Transceiver Test and Signal Generator Calibration

HEWLETT PACKARD

THE 8662A RF SYNTHESIZED SIGNAL GENERATOR

THE MOST VALUABLE SIGNAL GENERATOR IN THE WORLD

- Precision synthesized signal generator
- Exceptional spectral purity
- Microprocessor control
- Digital sweep capability

Very simply, the 8662A is the best signal generator in the world. It is the 8662A's unprecedented combination of RF performance and operating features that make it the best. Let's look at our 4 major areas of contribution in detail.

PRECISION SYNTHESIZED SIGNAL GENERATOR

Frequency:

- Range – 10 kHz–1280 MHz
  - Low freq allows testing of lowest AM bands and all IF's
  - 6 decade frequency range for LO applications
  - Frequency agility to test cellular and priority channel receivers
  - Testing receivers that require low freq digital unsquelching signals
- Resolution – 0.1 Hz
  - High resolution for narrow-band device testing
  - Frequency repeatability for component testing
- Stability – 5×10^{-10}/day
  - Ideal lab frequency standard
  - LO for narrow-band receiver

First, it's a precision synthesized signal generator and it makes improvements in almost all specification areas over the 8660 and competitive generators. It covers a frequency range from 10 kHz to 1280 MHz in a single unit, a convenience not provided by the 8660, which requires 2 plug-ins to cover the same range. It has a frequency resolution of 0.1 Hz, as compared to the 1 Hz resolution offered by many competitive generators. It has excellent stability – 5×10^{-10}/day – as a standard feature.

PRECISION SYNTHESIZED SIGNAL GENERATOR

Output:

- Range – +13 dBm to –139.9 dBm
  - Power to drive high level mixer
  - Wide range for testing the most sensitive receivers
- Resolution – 0.1 dB
  - Allows more precise sensitivity measurements
- Accuracy – ±1 dB
  - Allows more accurate sensitivity measurements
- Reverse power protection – 30 watts

Modulation

- AM to 95%
- FM, dc to 100 kHz

We've also made significant contributions in output characteristics.

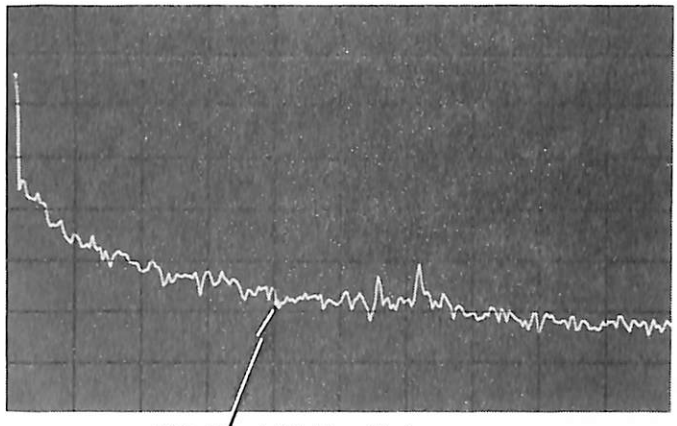
It has an output level range from +13 dBm to –139.9 dBm with an overrange capability to +16 dBm at almost all frequencies. The output resolution is 1/10 of a dB, not 1 dB as you'll find on most programmable signal generators. And, a very important specification, the output level accuracy is ±1 dB from +13 dBm to –120 dBm. This accuracy is very important in receiver tests; it will allow you to have much better specs on your products, as you can test them much more accurately.

And finally, since we know the 8662 will often be used in transceiver test applications, we have provided reverse power protection up to 30W as a standard feature.

We have AM modulation to 95% depths, and FM modulation from dc to 100 kHz rates, and up to 100 kHz deviations. Note also that in the doubler band, FM deviation is available to 200 kHz deviations.

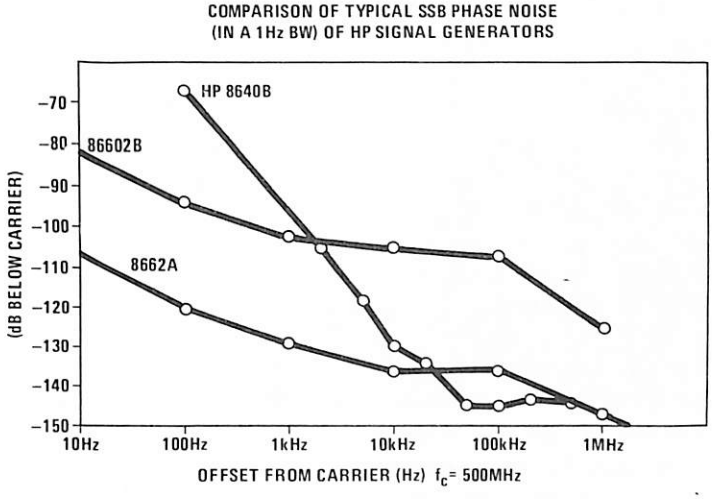
EXCEPTIONAL SPECTRAL PURITY

- Lowest phase noise of ANY signal generator
  - Low noise LO applications
  - Allows automation of adjacent channel selectivity testing
- Low spurious signals (–84 to –100 dBc)



−118 dBc at 10 Hz offset

Residual SSB Phase Noise. f_c=159 MHz. 10 dB/div.



Next, and the 8662A's most significant contribution is spectral purity. The 8662A has the lowest phase noise of any synthesized source or any synthesized signal gnerator in the world today. Many customers will buy the 8662 for its phase noise alone.

In addition, the 8662A makes a 10—20 dB improvement over the 8660 in spurs, specified down as much as 100 dB, and typically much lower than that. This plot is a picture taken on an HP 3582, and it shows phase noise at a 10 Hz offset from the carrier down 118 dB. That is by far better than any other signal generator available today.

Let's compare the 8662A to our own HP top of the line generators, the 8640 and the 8660 using the 86602B 1300 MHz RF plug-in. This graph shows typical SSB Φ noise, at a carrier frequency of 500 MHz. You'll see that the 8662 is 20—30 dB better than the 8660 @ all offsets from the carrier.

With respect to the 8640, you see that at a 20—50 kHz offset, a typical receiver channel spacing for that adjacent channel testing, the 8662 and the 8640 have comparable noise. The 8640 dips down a bit in this region, but their noise floors are roughly the same. So you see we really are comparable to the finest cavity tuned generator in the world — the 8640.

MICROPROCESSOR CONTROL FOR MEASUREMENT EFFICIENCY

- Full keyboard control
- Incrementing of all functions
- Store/recall of 9 complete front-panel setups
- Sequence
- Friendly HP-IB with learn mode
- Rear panel control connector
- Special functions, eg. freq. offset, dB relative, re-initialization
- Battery protected memory
- Self-Test

Our 3rd major contribution we've called measurement efficiency. We've used an advanced microprocessor based controller that gives the 8662 a broad range of operating features not found on any other signal generator.

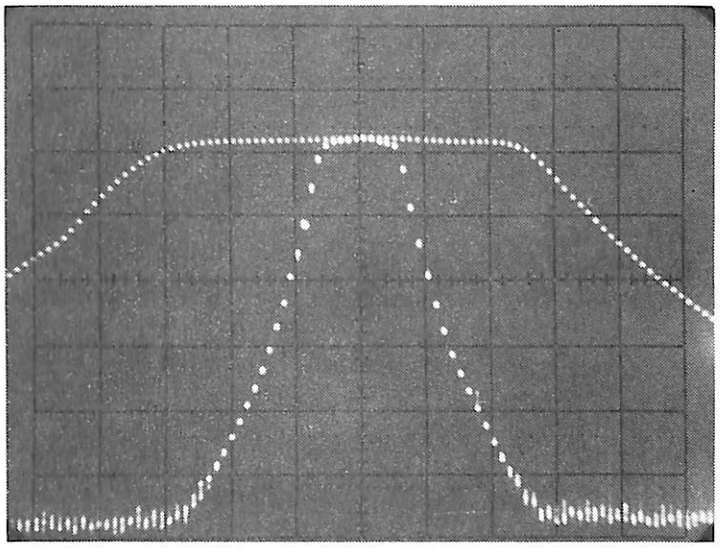
We have full keyboard control of all functions. The 8662A is the only available synthesized signal generator with full keyboard control. We can increment all functions, using the step-up/step-down keys or the RPG (rotary pulse generator). 9 full front panels can be stored and then recalled later. We can also set sequences of any number of those front panels, and recall that sequence with a single keystroke. Finally, we've made a major contribution in ease of HP-IB programming, and have incorporated learn modes.

The 8662A has a rear panel control connector, which allows you to remotely control 6 front panel functions, including sequence and step up/step-down with a simple external contact closure to ground. We've also taken advantage of the microprocessor to incorporate some special functions such as frequency offset, amplitude settable in dB relative to any level, and a re-initialization function.

Not only are current front panel settings protected, but all 9 memory locations are battery protected. This can be important for power line failure protection or for mobile test stations.

PRECISION DIGITAL SWEEP

- Synthesizer resolution and accuracy
- Swept testing of crystal filters
- Start/Stop and span (Δf) sweeps
- Linear sweep with user-defined step size
- Log sweep with 1% or 10% logarithmic steps
- Five time-per-step selections (0.5, 1, 2, 10, 100 ms/step)
- Five digital intensified markers



Finally, our last major contribution combines fast switching speed and microprocessor control to give the 8662A a unique sweep capability. This is an extremely powerful digital sweep — in fact, the 8662A has even more features than any HP sweeper! Probably the most important contribution is that in the sweep mode, the 8662A maintains *synthesizer resolution and accuracy,* unlike a normal sweeper. Though it is a point-by-point sweep and not a continuous sweep, you can make the steps as small as you care to.

We have both start/stop and span sweep modes, or as it is called in a normal sweeper, the Δf mode.

There is a linear sweep, where you can set any step size, and a logarithmic sweep with 1 or 10% logarithmic steps. Log sweep is extremely useful when covering a broad frequency range, or when a log scale x-axis is desired. This is a unique feature of the 8662A. You can choose between 5 time-per-step selections, from ½ ms to 100 ms/step, and of course, since we are a sweeper, we have 5 digital markers, both amplitude and Z-axis markers, again with the resolution and accuracy of the 8662A.

This is a photo taken on an HP oscilloscope, displaying both the wide-band and narrow-band characteristics of a filter using the sequence function.

HP-IB PROGRAMMING

Front panel
Keyboard sequence: [Frequency] [9] [.] [2] [MHz]
HP-IB: FR 9.2 MZ

Keyboard sequence: [Amplitude] [1] [1] [0] [MHz] —dBm
HP-IB: AP110-D

Learn modes
- Learn front panel mode
  - complete front panel information
- Learn backplane
  - "fast" learn mode; stores frequency and modulation information only

We mentioned earlier the ease of HP-IB programming. I don't know how many of you have ever had the unique opportunity to program an 8660, but I'm sure you've all heard the stories about how the digits go in backwards, how it uses special secret symbols to control different functions. Now HP-IB programming is as simple as pressing the front panel keyboard. Let's look at an example and see how this works.

On the front panel, if we wanted to set a frequency of 9.2 MHz, we would push the frequency key, then 9.2, then the MHz key. The HP-IB programming is just that easy, too. FR9.2, with the decimal point, with no concern about leading zeroes, and then MZ. Note the complete correspondence between the HP-IB command and the front panel sequence. Amplitude can be programmed in the same way. Here we would push the Amplitude key, 110, – dBm. The HP-IB command is AP110-D. Very, very straightforward.

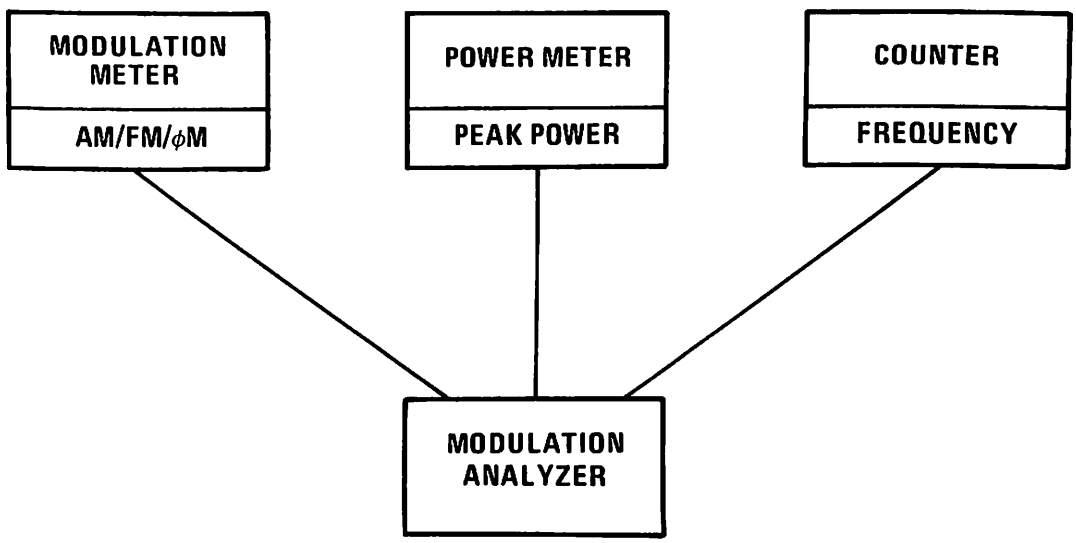
We've also supplied two different learn modes. In the first, you can simply store away the entire front panel set-up in the controller.

The second is the backplane fast learn mode, which stores frequency and modulation information only, and is used to enhance our frequency switching speed.

THE HP 8901 MODULATION ANALYZER

CONVENTIONAL INSTRUMENTATION FOR MODULATION CHARACTERIZATION

	POWER	MODULATION	FREQUENCY
Power Meter	Yes	Very Limited	None
Spectrum Analyzer	Limited	Limited	Limited
Modulation Meters	None	Yes	None
Counters	None	Very Limited	Yes



THE MODULATION ANALYZER CONCEPT

MODULATION TYPES

ANGULAR (Exponential)
- Frequency Modulation
- Phase Modulation

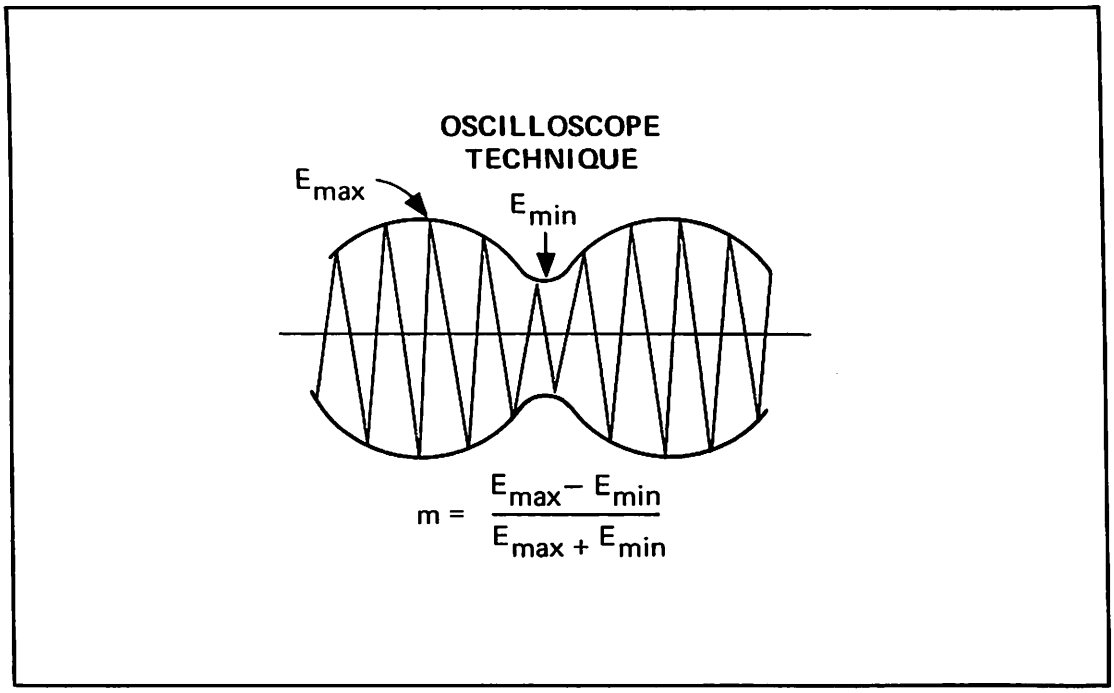
AMPLITUDE
- Amplitude Modulation

Now let's talk about modulation. Modulation is the alteration of a signal to carry information. The only two signal parameters that can be changed are amplitude and angle (phase or frequency). All modulation is one form or the other or a combination of both. Let's briefly examine how customers are presently making modulation measurements and how the 8901A can help them make these measurements better.

AM MEASUREMENT TECHNIQUES

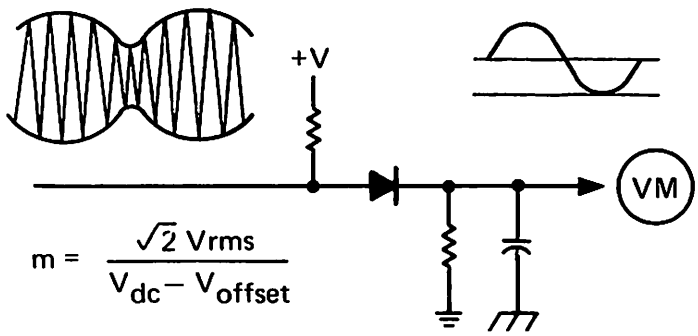
- Oscilloscope
- Diode Detector
- Spectrum Analyzer

First let's look at amplitude modulation. The three most common techniques for measuring AM use either a scope, diode detector, or a spectrum analyzer. Let's examine the merits of each method.



Measuring AM depth by the oscilloscope technique is accomplished by measuring E_{max} and E_{min} and calculating the modulation index using the formula shown. One advantage of this technique is that the total signal is visible. A disadvantage is that to achieve reasonable accuracy the carrier frequency should be less than half the scope bandwidth. Accuracy is between 1.5% and 10% and is limited by CRT resolution, linearity, and operator skill. This method cannot be automated. FM cannot be measured with an oscilloscope.

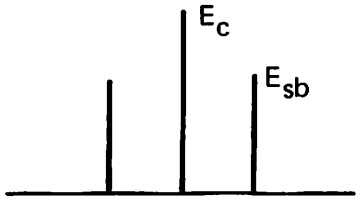
DIODE DETECTOR TECHNIQUE



The diode detector technique (sometimes referred to as the direct conversion technique) employs a diode and RC network to recover the AM. The detector dc offset must be measured and calculated. The dc detector voltage is proportional to the AM signal. AM depth is determined by measuring ac voltage, V_{rms}, dc voltage, Vdc, and calculated using the formula shown. Normally the diode is biased as shown. Typical accuracy is about 3%. This is the technique used in Big Foot. The drawbacks to this technique are:

1.) RF feedthrough is considerable which makes distortion measurements difficult.
2.) The detector offset varies with RF carrier frequency.
3.) The technique is valid only for sinusoidal modulation signals.

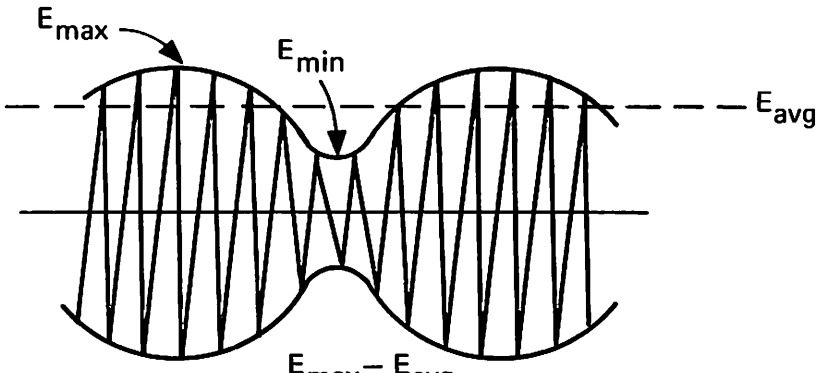
SPECTRUM ANALYZER TECHNIQUE



$$M_+ = 10^{\left(\frac{E_{sb(dB)} - E_{c(dB)} + 6dB}{20}\right)}$$

The spectrum analyzer technique is another common method for measuring AM, particularly for very small depths. The carrier and one AM sideband are measured with the spectrum analyzer and the AM depth is calculated with the formula given. One advantage of this technique is AM distortion can be measured directly. A disadvantage is that incidental FM causes uneven AM sidebands resulting in uncertainties. Another disadvantage is AM cannot be separated from FM. Often what looks like distortion is really incidental FM, not true AM distortion. Accuracy is typically 6% of reading.

AM MEASUREMENT WITH THE 8901A



$$m+ = \frac{E_{max} - E_{avg}}{E_{avg}}$$

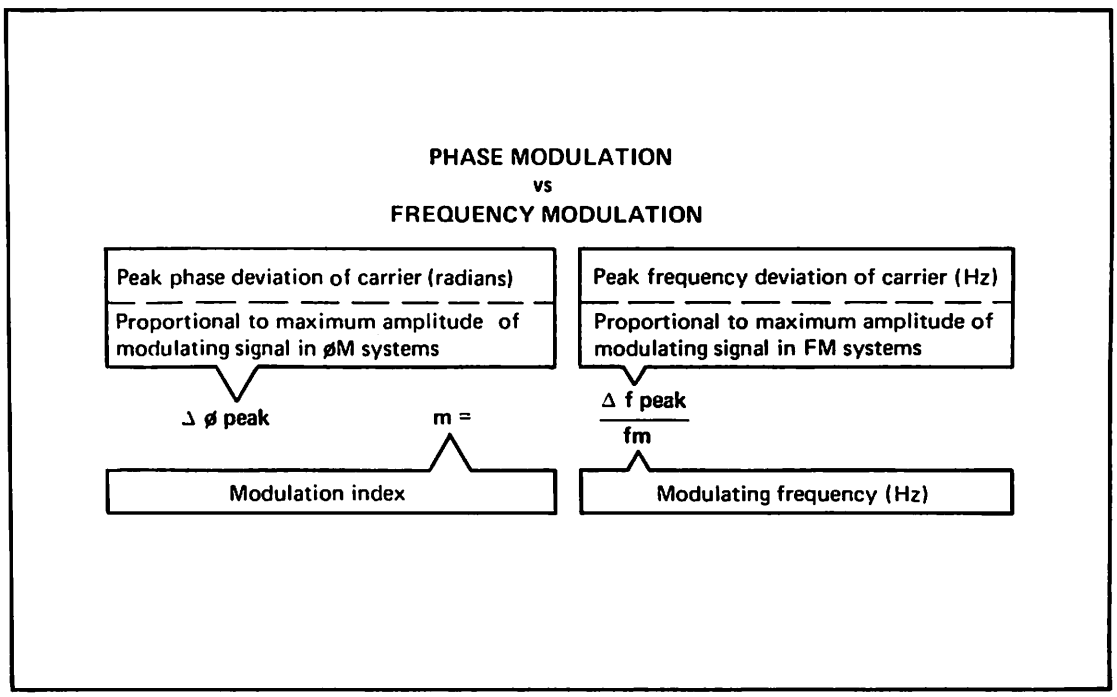
$$m- = \frac{E_{avg} - E_{min}}{E_{avg}}$$

You may have noticed that each technique so far uses a different formula to calculate AM depth. Customers usually want to calculate AM using the peak RF to average ratio. This is the way the 8901A measures AM using a modified RF detector technique. The 8901A measures the peak, E_{max}, calculates AM depth using the formula shown, and displays the result. Selectable peak detectors allow true measurement of + peak or – trough which is especially important on distorted modulation waveforms encountered in modulation limiting testing. Accuracy is ±1% of reading. Other advantages include low distortion on the recovered waveform and high FM rejection.

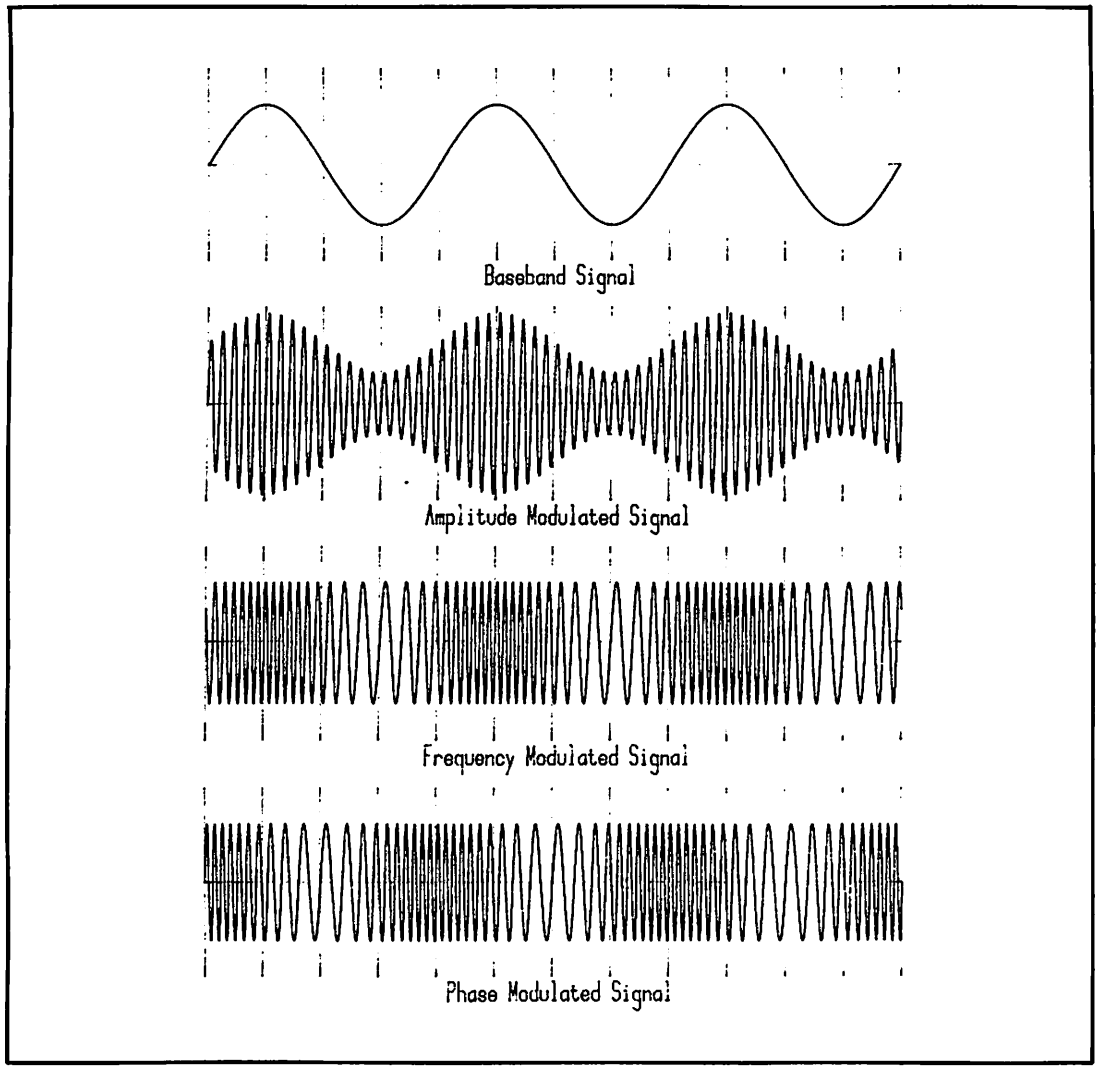
ANGLE MODULATION (EXPONENTIAL)

FREQUENCY MODULATION
PHASE MODULATION

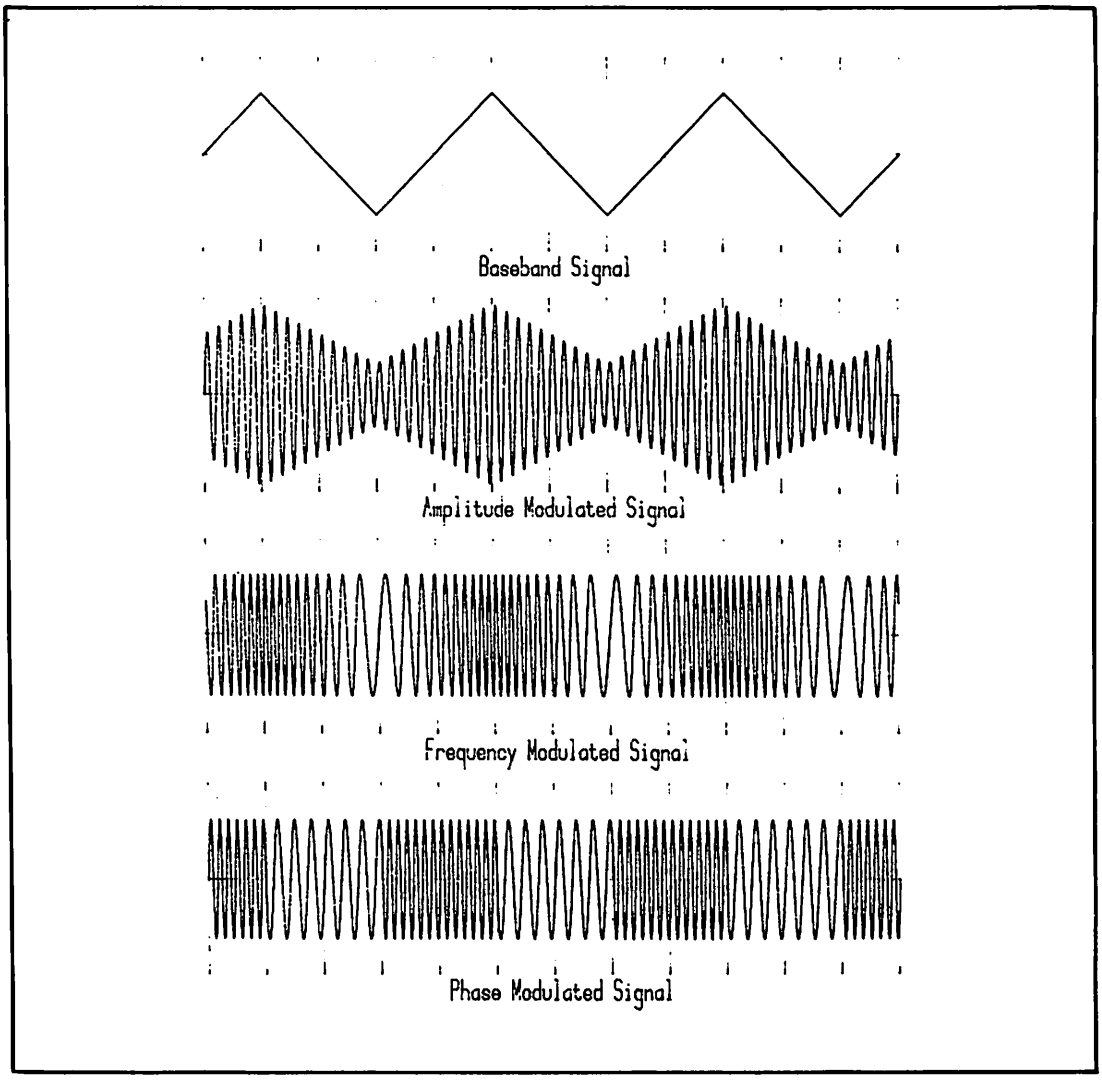
Now let's examine angle modulation. The two basic types are phase and frequency modulation, ϕM and FM. These are so similar that many people (factory types especially) get confused as to the difference if any. Let's quickly clear it up once and for all. We do this by examining various signals in the time domain.



Peak phase deviation is proportional to the maximum amplitude of the modulating signal and is equal to the modulation index. In FM systems, the peak frequency deviation is again proportional to the maximum amplitude of the modulating signal; however, the modulation index is equal to the peak deviation divided by the modulation rate.

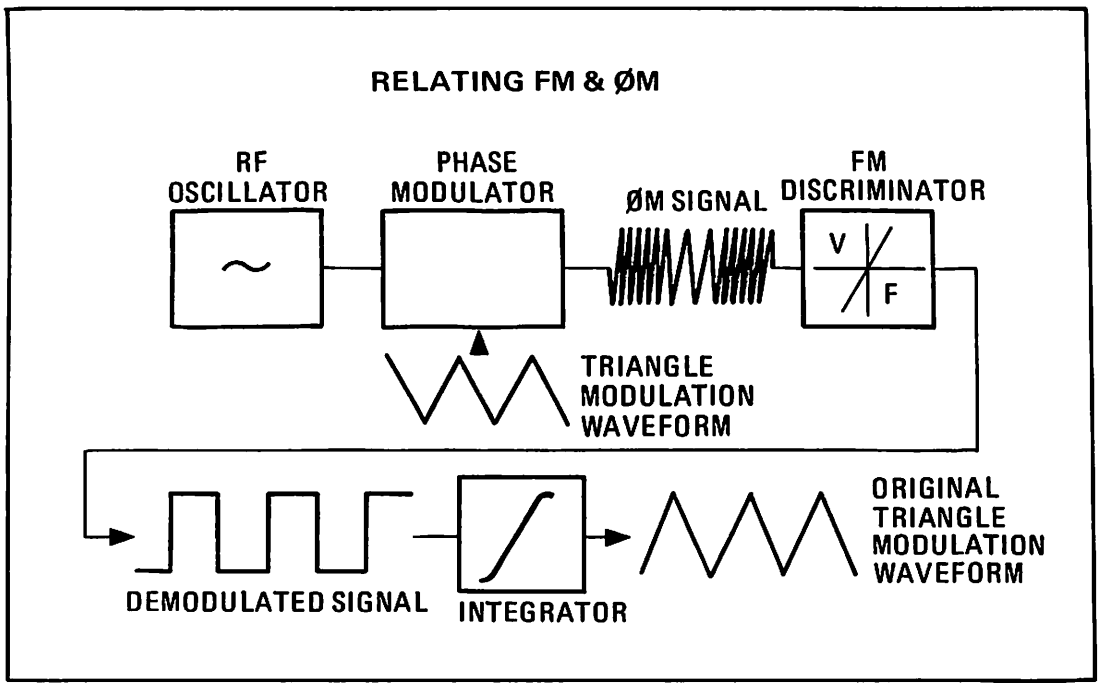


Here is a sinusoidal modulating signal and the resulting FM and ϕM signals. It is impossible to distinguish the difference unless the baseband signal is compared to the resultant modulated signals. Notice that the only difference between the FM and ϕM signal is a 90° phase shift since ϕM is the integral of FM. The real difference is more easily understood with a triangular modulating signal.



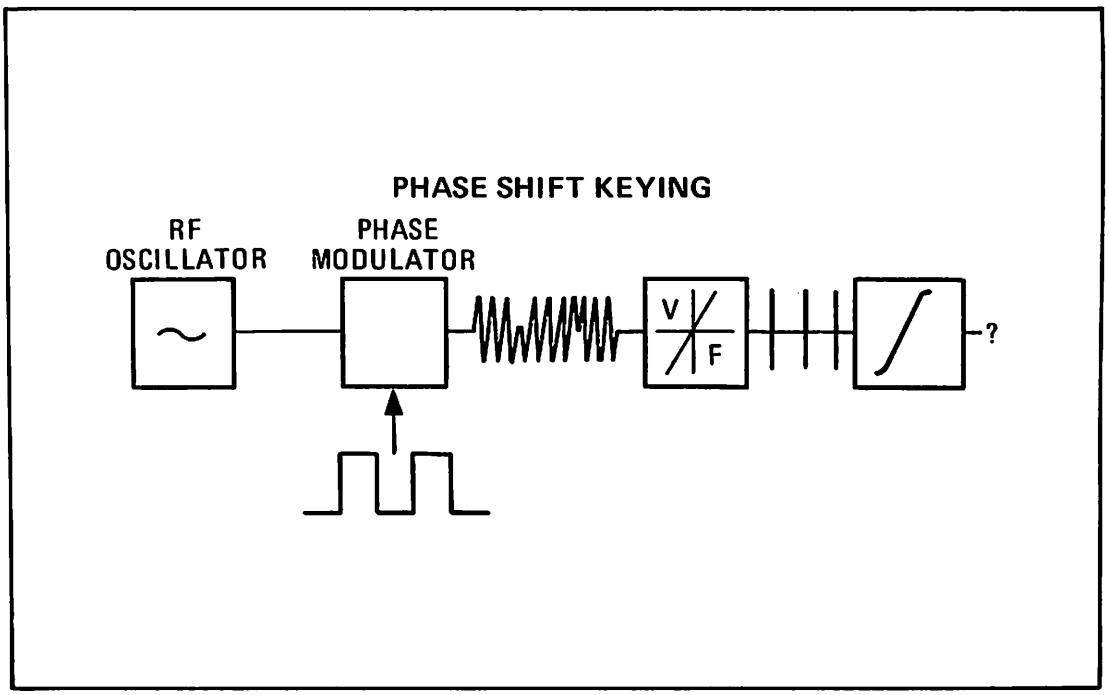
Notice that as this modulating signal increases at a constant rate, the FM signal increases in frequency at a constant rate, while the ϕM signal switches higher in frequency and thus advances or accumulates a positive phase at a constant rate. On the downward ramp the FM signal decreases linearly in frequency, while the ϕM signal decreases linearly in phase.

To best see the relation between ϕM and FM, let's see what happens when we phase modulate and then FM discriminate this signal.



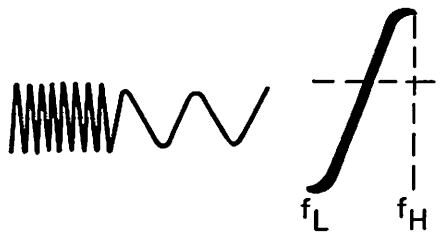
Notice that as before the phase modulated signal appears like two discrete frequencies. When this signal is passed through an FM discriminator, the result is a square-wave which is the derivative of the original triangle waveform. The original triangle signal is recovered by integrating.

Many FM systems actually operate this way. Instead of FM modulators, they use phase modulators. This is usually referred to as pre-emphasis because higher modulation rates are emphasized (6dB/octave). The receiver's FM—discriminate the signal and then integrate it. The 8901A also recovers phase modulation by integrating the output of the FM discriminator. For most modulation waveforms but not all, ϕM can be recovered by FM discriminating and then integrating.



Phase shift keying employs a square-wave modulating signal. The instantaneous phase transitions represent infinite frequency excursions to the FM discriminator. Thus, the discriminator output is a series of alternating "infinite" spikes which saturate the output and the modulation cannot be recovered. For this reason the 8901A cannot measure PSK signals.

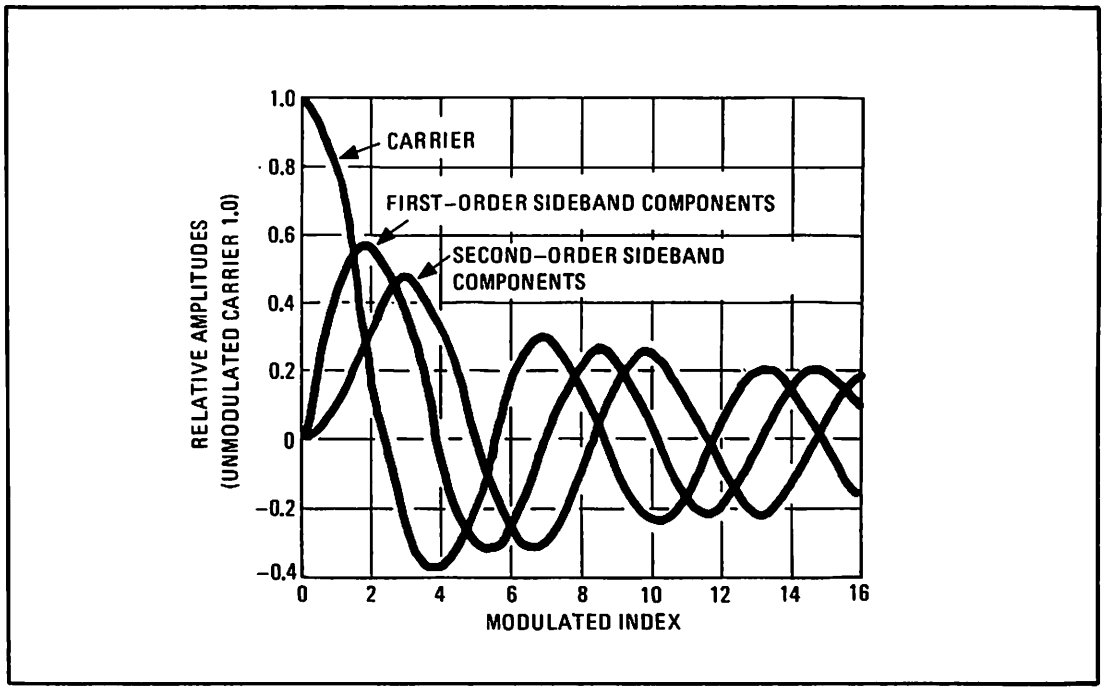
HOW IS FM MEASURED



PULSE COUNT
(5210A)
PHASE LOCK LOOP
EDGE DETECT (FILTER)

DISCRIMINATOR
(FREQUENCY TO
VOLTAGE CONVERTER)

The three basic ways of measuring angle modulation are with pulse count discriminators, phase lock loops, and edge detecting using filters. Unlike AM where the measuring system can be calibrated directly, FM discriminators must be calibrated with an FM signal with known modulation.

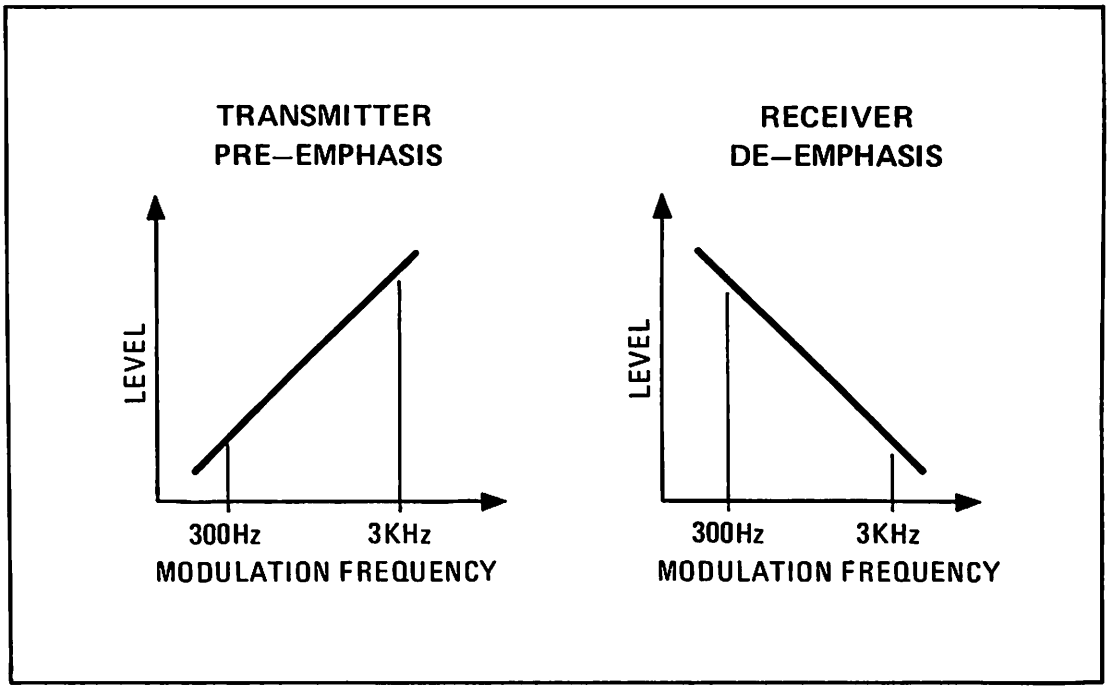


This is usually accomplished using the spectrum analyzer Bessel Null technique. At various modulation indexes the carrier amplitude goes to zero. The first null occurs at m=2.41. Thus, if FM deviation of a signal generator is adjusted to produce the first carrier null at 1kHz modulation rate, 2.41kHz deviation is produced (a 2.079 kHz rate results in 5kHz deviation). This signal could then be used to calibrate an FM discriminator.

BESSEL NULL ERRORS

- Limit to depth of Null
- FM distortion
- Incidental AM

Although the Bessel null technique is presently the most accurate way to generate a precise amount of FM deviation, the accuracy is sensitive to several things. One limiting factor is the ability to null the carrier as viewed on the spectrum analyzer. In addition, FM distortion and incidental AM cause the apparent null to shift thus degrading accuracy. As a result, accuracy is limited to about 2 to 4%. The 8901A measures FM with a very flat charge-coupled discriminator which is similar to the pulse-count type. It is this flatness combined with the calibrators 0.1% accuracy that provides 1% of reading FM performance. This truly represents a significant advance in the state of the art in FM measurement.



In most FM systems, a signal-to-noise improvement is accomplished by boosting high frequency modulation rates in the transmitter and attenuating these rates by the same amount in the receiver. The boost in the transmitter is 6dB/octave (which is the same as 20dB/decade) with the 3dB corner specified by a characteristic time constant for each FM system. The standard time constants are:

25μs for Dolby broadcast FM
50μs for European broadcast FM
75μs for U.S. broadcast FM
750μs for narrowband FM mobile radio

In order to faithfully reproduce the original modulation signal, the receiver must remove this boost (pre-emphasis) using a single pole (6dB/octave) de-emphasis filter. Accordingly, the 8901A contains de-emphasis filter networks for all the major FM systems including broadcast FM and mobile radio.

SPECIALIZED MODULATION TYPES

Amplitude	Angle	Combination
Pulse	FSK (Frequency Shift Keying)	AM Stereo (future)
SSB (Single sideband)	MSK (Minimum shift keying)	
DSSC (Double sideband suppressed carrier)	PSK (Phase shift keying)	
TV (Video)		

Besides the basic modulation formats we've already discussed, there are other specialized types of modulation. The 8901A is ideal for demodulating and making measurements on FSK. It will also be ready when AM stereo finally materializes. Several of the proposed AM stereo systems are a combination of AM and FM (ϕM) modulation. The 8901A has limited capability for MSK, SSB, and Pulse signals and cannot be used for the other modulation formats shown. A more complete description for each case is included below.

SOME Pulse - The 8901A has only limited capability. Most signals cannot be measured, only those with high duty cycles (no TACAN, DME, or radar).

NO SSB - The 8901A cannot demodulate SSB but can measure peak envelope power. Most SSB measurements require a spectrum analyzer.

NO DSSC - This requires a specialized receiver that re-inserts the carrier. The 8901A would improperly demodulate this.

NO Video (TV) - The 8901A does not have the required bandwidth.

NO PSK - The 8901A cannot measure this unless rise and fall times are lengthened.

YES FSK - The 8901A does this exceptionally well especially using the >20kHz filter.

YES MSK - The 8901A is useful for this type of signal.

YES AM Stereo - Several of the stereo AM proposals involve simultaneous AM and ϕM. The 8901A is ideal for this because of its high rejection of AM on FM and FM on AM.

MODULATION ANALYZER REQUIREMENTS

I. As a Precision Receiver

A. Measure and Recover AM/FM/ϕM with greatest possible accuracy.

B. Linear Detectors for Low Distortion Audio/Video

C. Independent Detectors for Measurement of Incidental AM and FM (ϕ)

D. Low Noise for Residual AM and FM Measurements

II. As a Power Meter

A. Peak Enveolope Power of RF

B. Peak Envelope Power of the Mod Analyzer IF

III. As a Counter

A. Count RF even in the presence of High Percentage AM

B. High Sensitivity

C. Selectively count RF in presence of larger signals

IV. Ease of Operation

A. AM/FM/ϕM/RF Power/Frequency measure with a single key stroke

B. Automatic tuning to the highest level RF signal present

C. Autoranging of RF attenuators and audio amplifiers

D. HP-IB control of all instrument functions

E. Microprocessor control for Data Corrected Displays

DESIGN GOALS

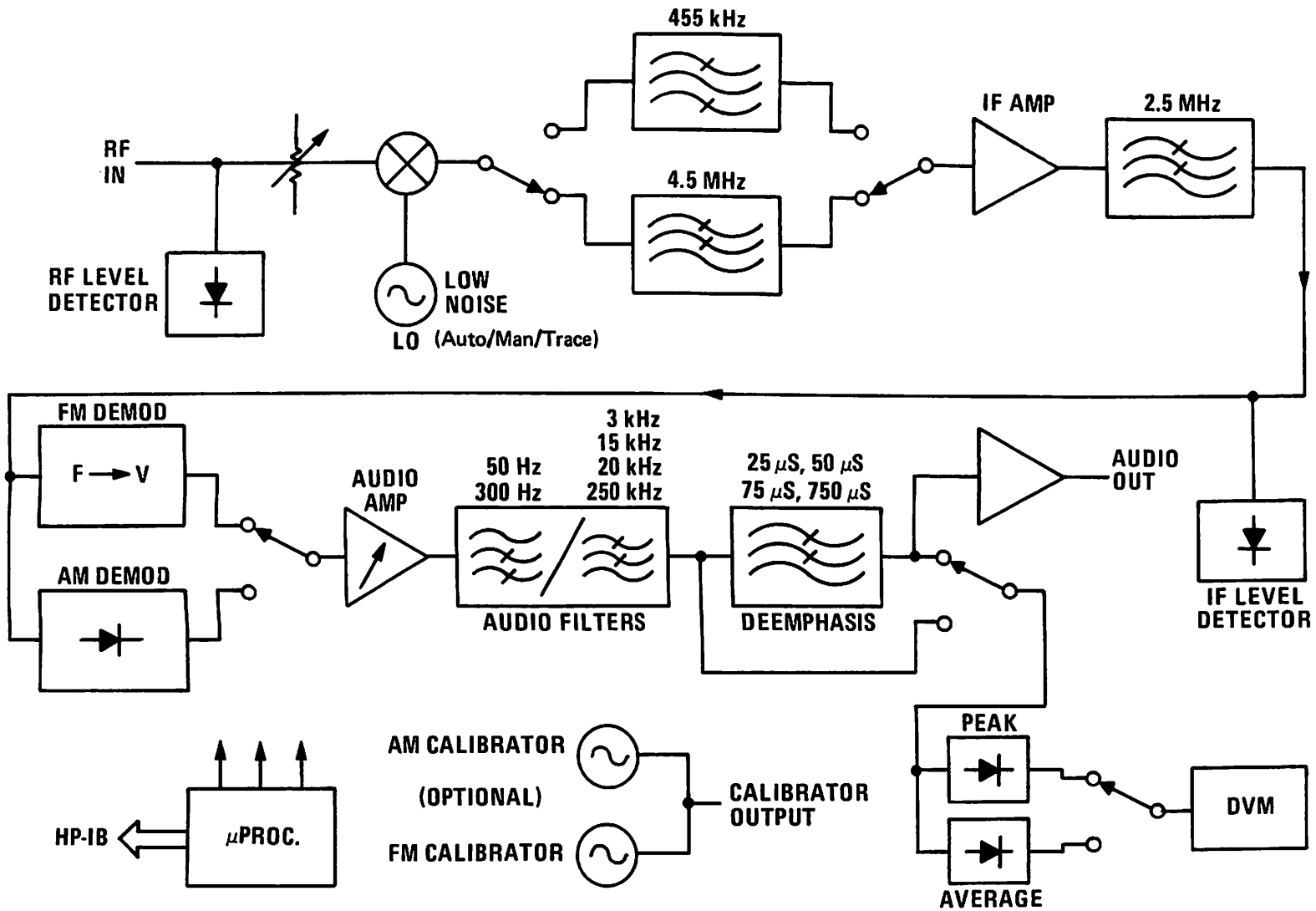
RF Input Frequency Range	150 kHz – 1300 MHz
RF Input Power Range	3 μW – 1W
RF Input Power Measurement	1 mW – 1W

AM Range	0–99%	20 Hz – 100 kHz rates	Accuracy ±1%
FM Range	0–400 kHz PK	20 Hz – 200 kHz rates	Accuracy ±1%
ΦM Range	0–400 Rad. PK	200 Hz – 20 kHz rates	Accuracy ±3%

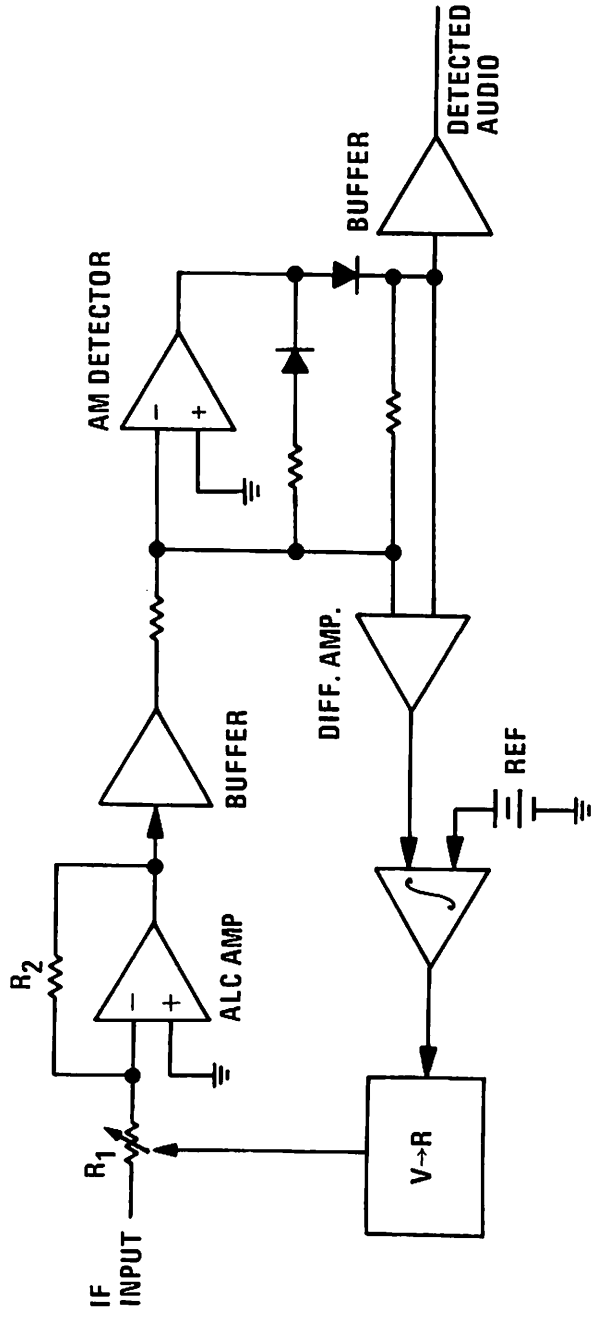
Counter

150 kHz – 1300 MHz Range
10 Hz Resolution
30 Hz Accuracy
–60 dBm Sensitivity

Internal Calibration (Optional)

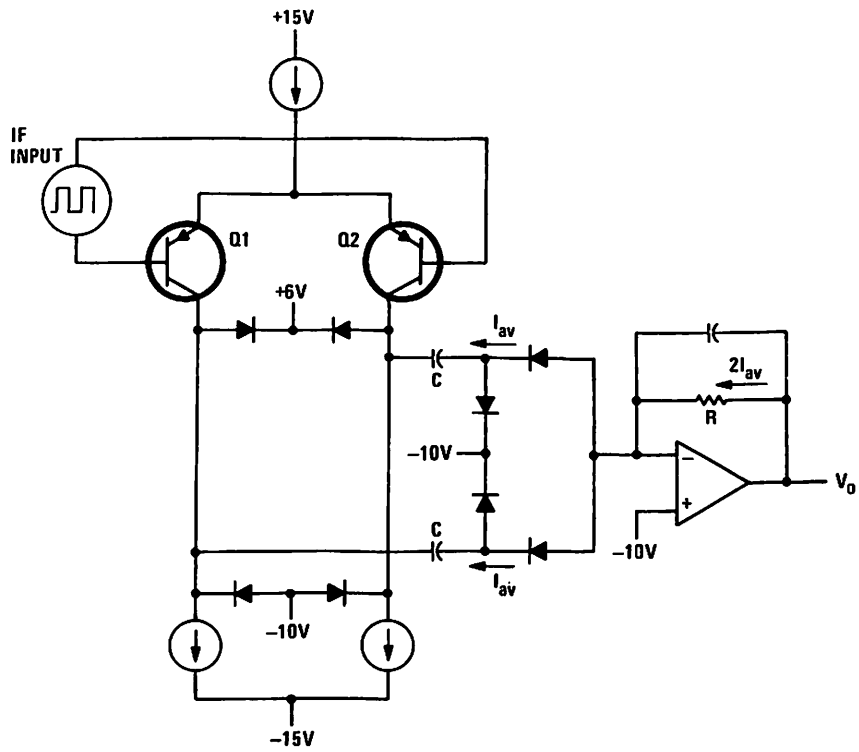


MOD ANALYZER BLOCK DIAGRAM



AM DEMODULATOR BLOCK DIAGRAM

FM DEMODULATOR



Charge Transferred in C During Each Cycle $Q = CV$

Average Current in C $I_{av} = CVF$

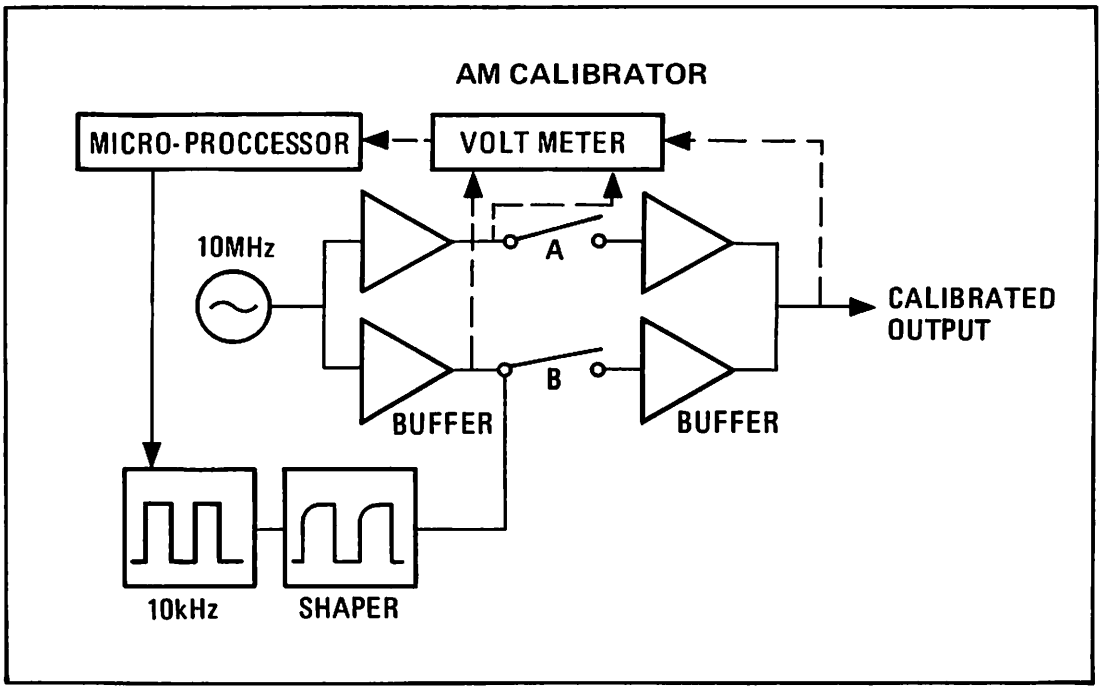
$$V_o = 2I_{av}R = 2CVRF$$

for $C = 20pF$, $V = 16.6V$ $R = 9600\Omega$

$$V_o = \left(\frac{6.4V}{MHz}\right) F$$

Linearity is achieved by causing the transfer function to be dependent on passive components.

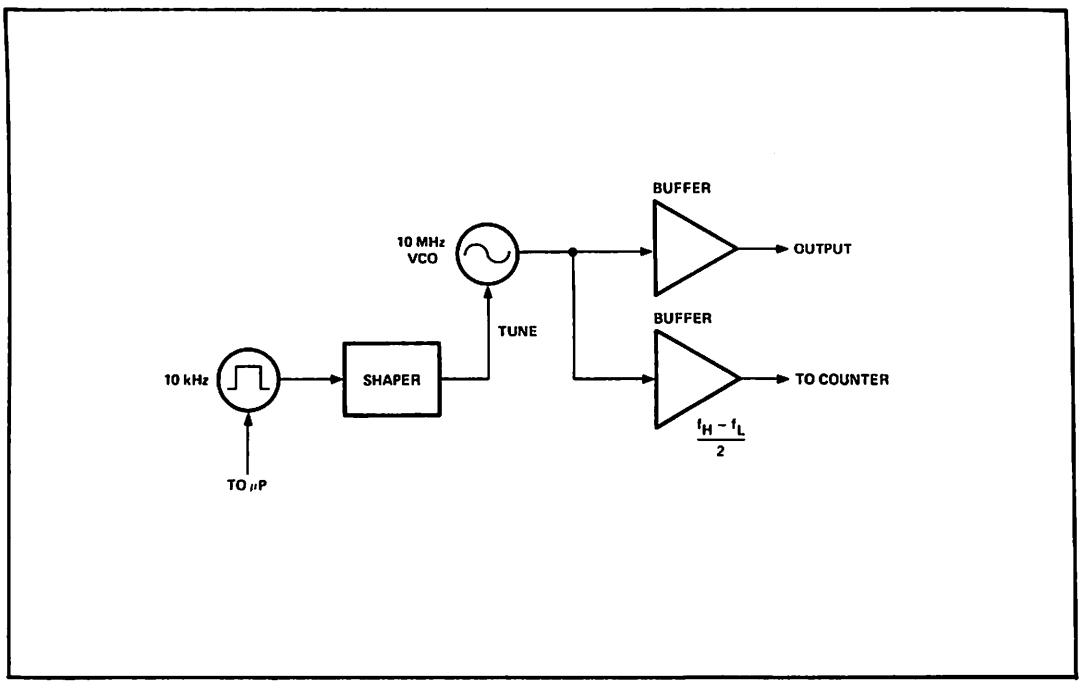
Low Noise is achieved because only noise at the end of the capacitor charge and discharge has an effect.



Let's examine the AM calibrator system to see how it works. A limited 10MHz signal is applied to two identical modulators (A & B) which are isolated by two identical buffer amplifiers. Modulator B is then switched on and off by a shaped square wave drive signal. After further isolation with two more buffers, the summed signals appear at the Calibrator Output. If both signal paths are identical (low differential phase shift) then the RF output voltage from the calibrator periodically varies from one RF voltage level to twice that level. Such a signal represents 33.33% AM.

Note that the voltmeter measures many points under microprocessor control. It makes measurements to specifically characterize each path and correctly calibrates for minor differences.

See application note 256-1



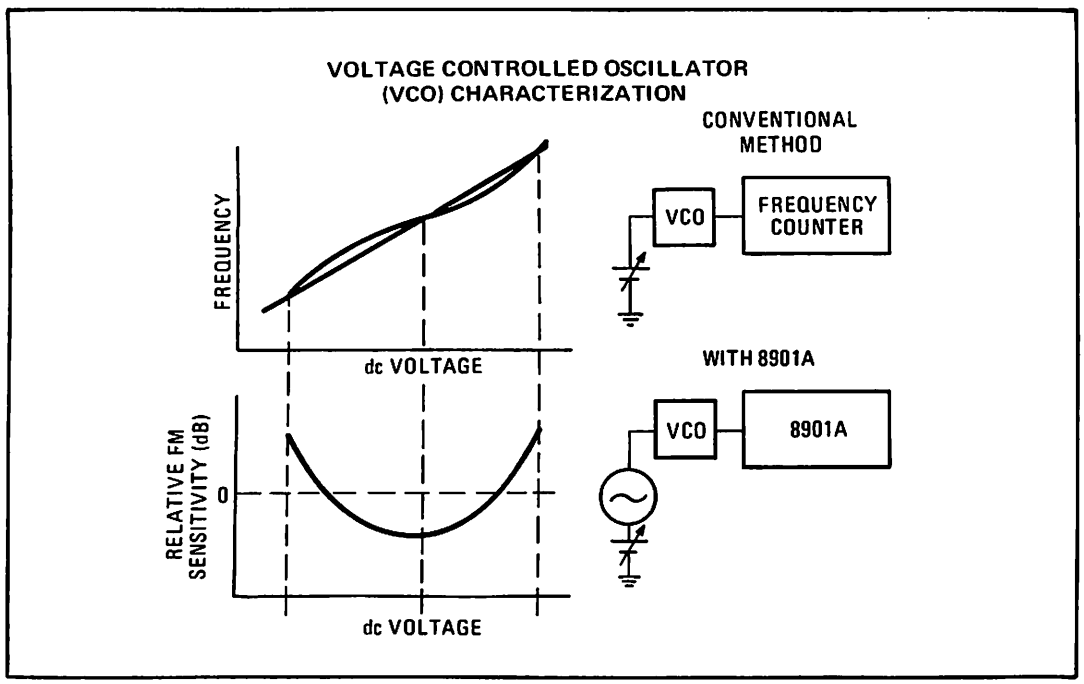
The FM calibrator is very similar to the AM. The same 10MHz source is now varied by a shaped square-wave to provide approximately 33kHz of peak FM deviation. When the calibrator button is pushed, the VCO input is switched to the high frequency (f_H) peak, and the frequency is measured by the 8901A's counter. Then the low frequency peak (f_L) is measured and the peak deviation is calculated as $\frac{f_H - f_L}{2}$. Sources of error have again been researched and minimized or calibrated out.

Our calibrators are a real contribution in the area of modulation measurements.

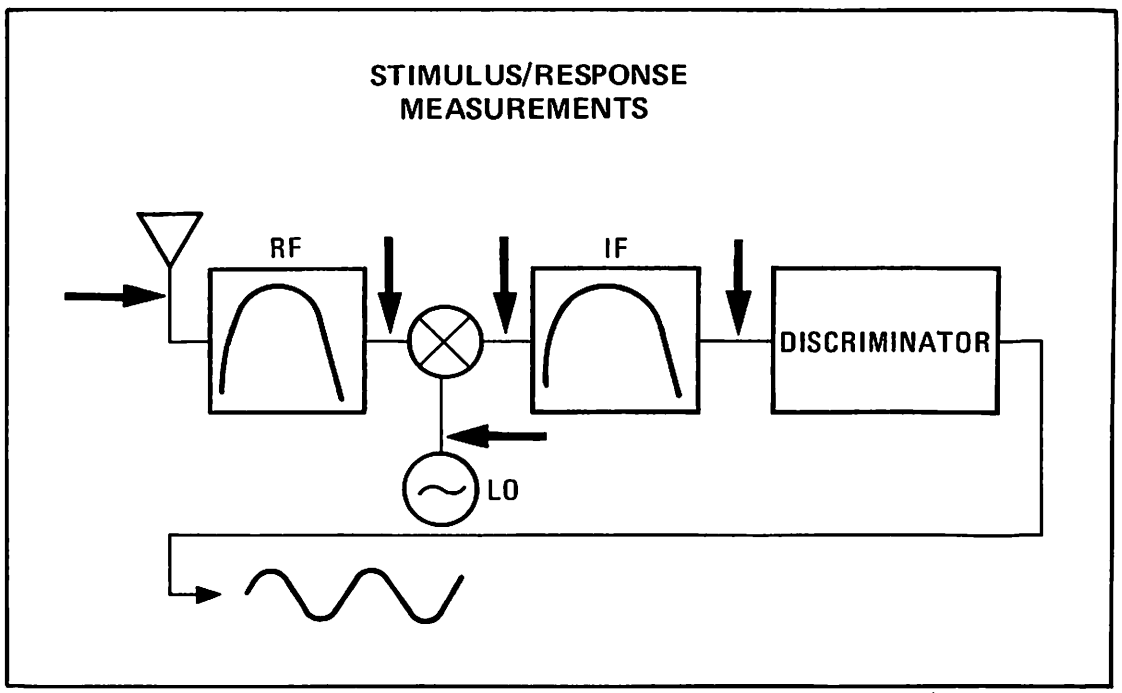
GENERAL R+D

- Oscillator Characterization
- Modulator Characterization
- Stimulus/Response Measurements

The 8901A is a very useful R&D tool. It can be used in a wide variety of applications other than transmitter testing. The 8901A is excellent for characterizing local oscillators.



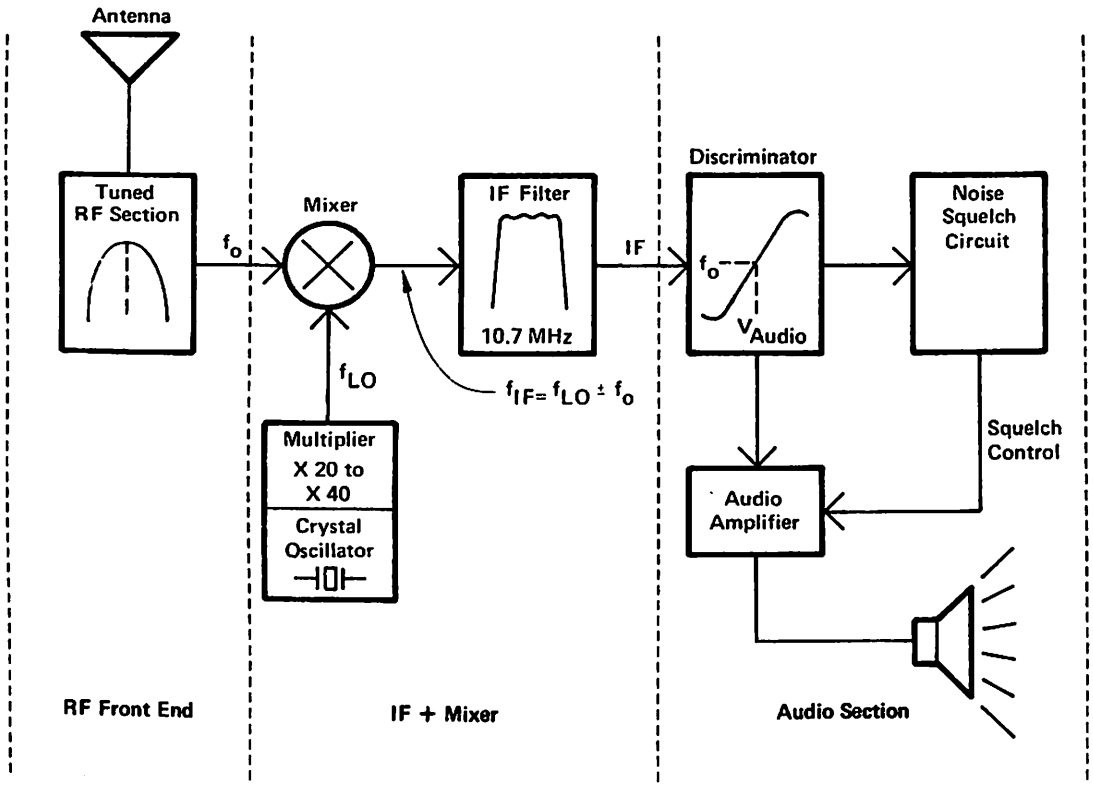
It can be used to measure residual FM. It can also help measure tuning linearity. By applying a dc tuning voltage to a VCO along with a small, constant-level ac signal, the 8901A can be used to count frequency and then FM deviation. Using ratio, linearity can be shown directly (RF frequency vs. FM sensitivity). Modulators can be characterized for distortion, residuals, incidentals, and sensitivity.



Another exciting application for the 8901A is in stimulus/response measurements. Take for example an FM receiver. If the audio output has difficulties when an RF signal is applied at the antenna input, there is a question of what element may be causing the problem. The 8901A can be used to monitor the signals at the points indicated by the arrows to isolate the problem. At each point, the residual noise, AM content, FM content, distortion, signal level, and frequency is checked. In this way, any element that creates AM to FM conversion, additional noise, or additional distortion is isolated.

TRANSCEIVER TEST
SIGNAL GENERATORS

LAND MOBILE SIMPLIFIED FM RECEIVER



RECEIVER TEST TERMINOLOGY

- Sensitivity
- Quieting
- Selectivity
- Squelch
- Channel Spacing
- Psophometric Filter
- Sinad

SENSITIVITY

The smallest RF signal that can produce an intelligible audio output signal from a receiver.

Determines how far the receiver can be from the transmitter and still receive an understandable message.

Typical Values:

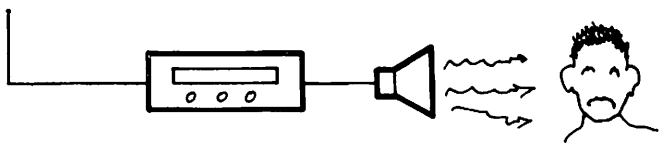
- **High quality FM mobile radio ..... 0.35 μV**
- **CB Radio ..... 0.75 μV**

EIA standard measurement methods.

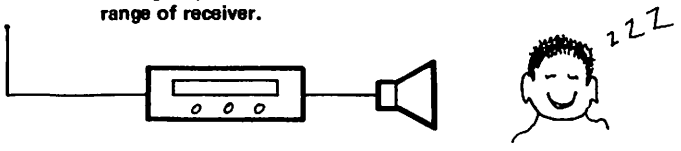
QUIETING

A measure of the noise reduction in the audio output of a receiver caused by an unmodulated carrier at the receiver frequency.

No RF signal present.



RF signal present within sensitivity range of receiver.



SELECTIVITY

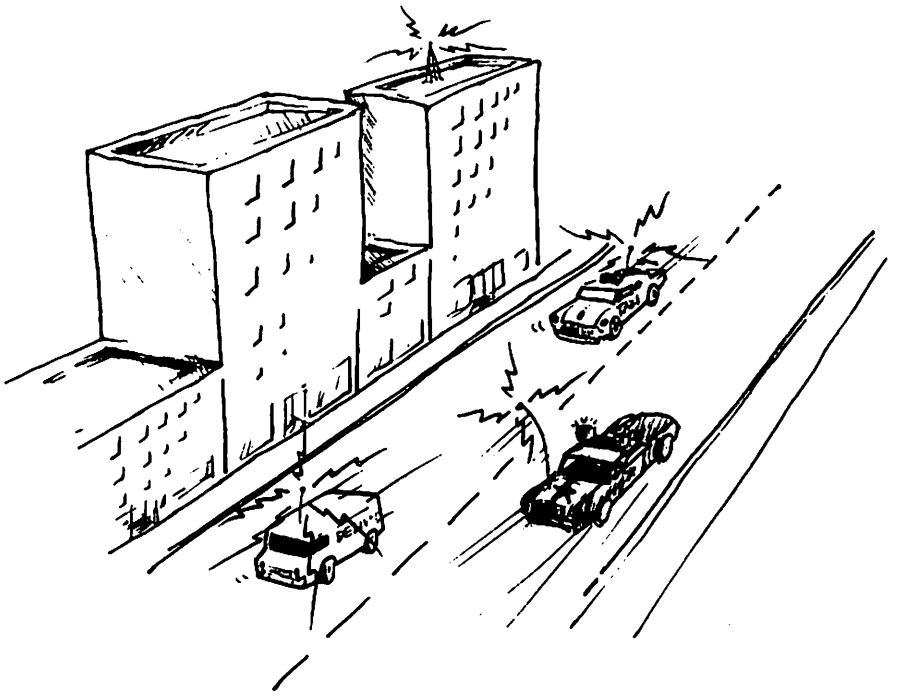
The ability of the receiver to select the desired signal and reject all others.

Determines if strong signals on closeby channels will cause interference.

Typical Values:

- **High quality FM Mobile Radio ..... 100 dB**
- **CB Radio ..... 50 dB**

adjacent channel selectivity



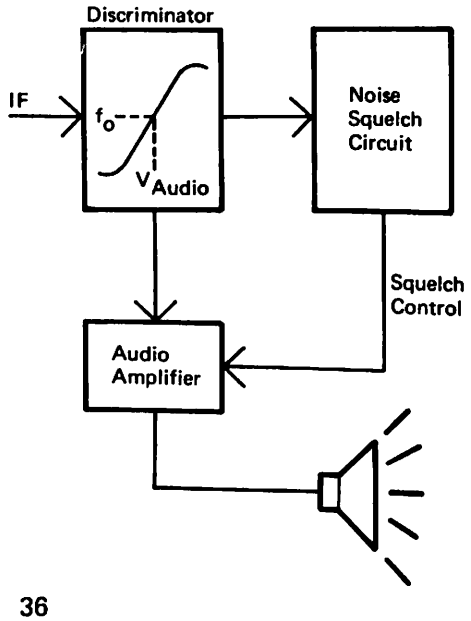
SQUELCH

The ability of the receiver to turn off the audio output when no signal is being received.

Two basic types:

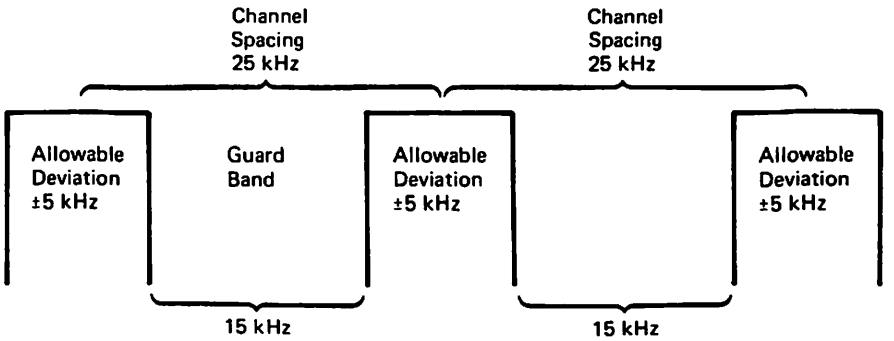
- **Noise squelch**
- **Tone coded squelch**

Tone requencing possible - because of ringing problem. But single tone @ c 150Hz is simplest arrangement.



CHANNEL SPACING

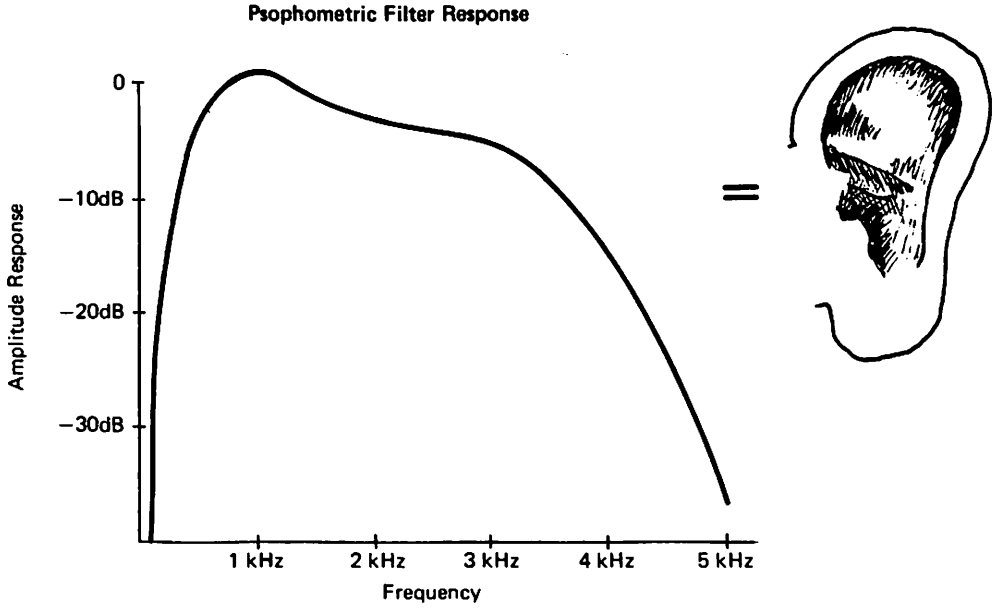
The separation between two adjacent assigned carriers. Typically 25 kHz in the U.S. As close as 12.5 kHz in Europe.



PSOPHOMETRIC FILTER

A filter designed to help reduce audio interference while passing voice type communication signals.

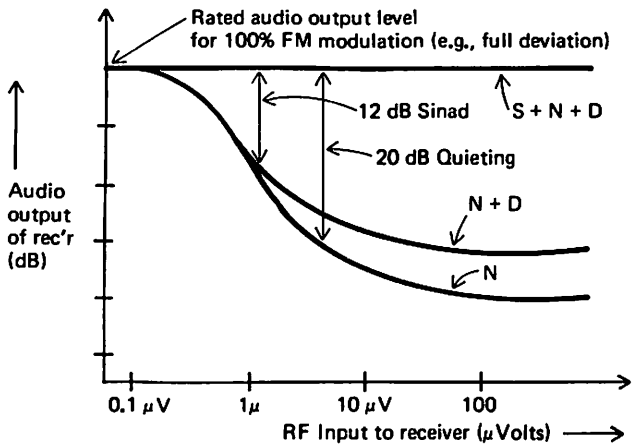
Psophometric Filter Response



MOBILE RADIO TESTS

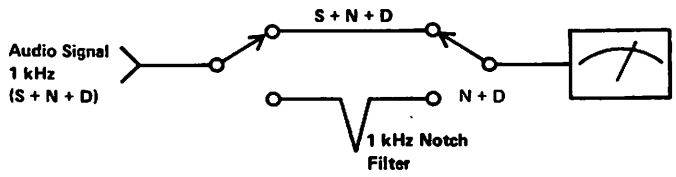
Definition "Sinad" = Ratio of signal + noise + distortion to Noise + distortion

$$\text{Sinad (dB)} = 20 \log_{10} \frac{S + N + D}{N + D}$$



SINAD

Determine ratio in dB of $\frac{S + N + D}{N + D}$

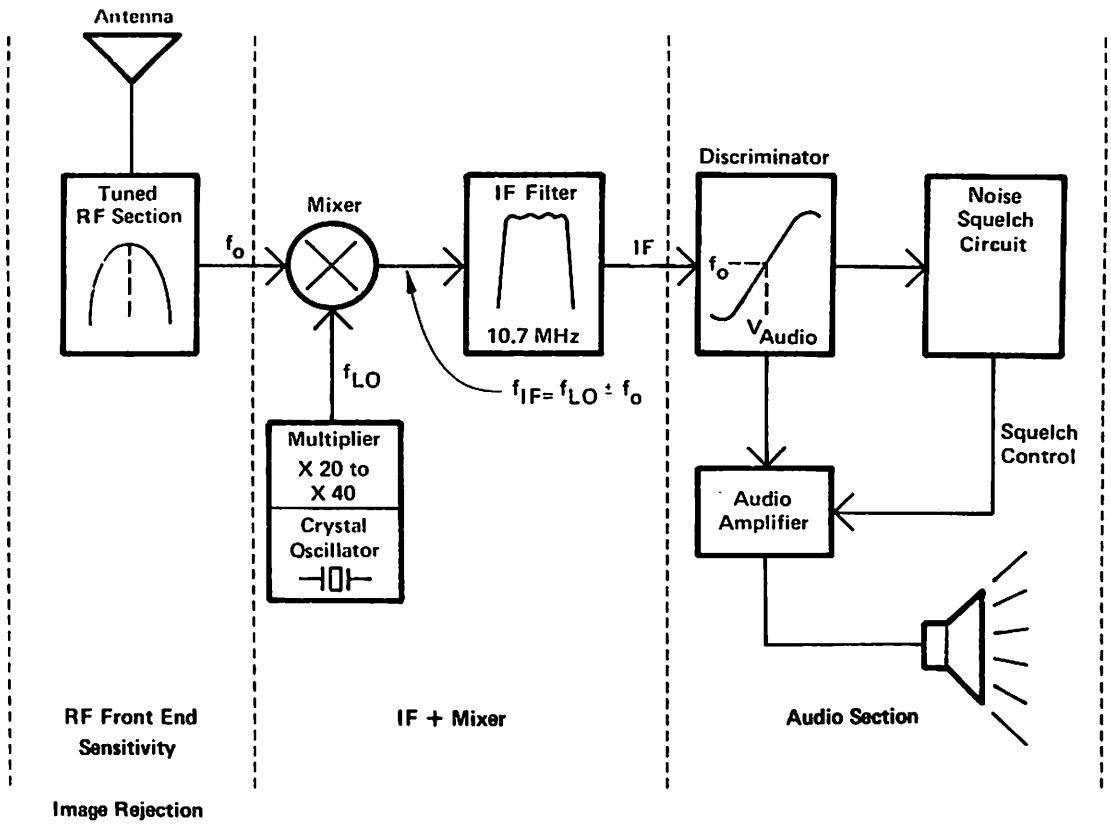


Test setup:

Test Procedure:

1. Apply test signal modulated with 1 kHz tone at 2/3 maximum rated deviation.
2. Set level (set a reference level of S + N + D).
3. Notch out the signal (switch to Distortion) and read ratio in dB of S + N + D/N + D.

LAND MOBILE SIMPLIFIED FM RECEIVER



SELECTED SPECIFICATIONS

MOTOROLA MICOR FM MOBILE RADIO

Frequency Range	132 – 174 MHz
Current Drain:	
Standby	0.45 Amp
Receive	2 Amps
Transmit	10.5 to 24 Amps

Receiver

Channel Spacing	30 kHz
Sensitivity:	
20 dB quieting	0.5 μV (0.25 μV with preamplifier)
EIA Sinad	0.35 μV (0.175 μV with preamplifier)
Selectivity	–100 dB at 30 kHz
Intermodulation	–80 dB
Spurious and Image Rejection	100 dB
Audio Output	10 watts at less than 5% distortion

Transmitter

RF Power Output	45 to 110 watts
Spurious & Harmonic Emission	–85 dB
Modulation	±5 kHz rated deviation
Frequency Stability	±0.0005%
Audio Distortion	Less than 3%

Price ≈$1400

TYPICAL RECEIVER TESTS:

USABLE SENSITIVITY

QUIETING SENSITIVITY

SQUELCH THRESHOLD

SPURIOUS ATTENUATION (INCLUDING IMAGE & IF REJECTION)

ADJACENT CHANNEL SELECTIVITY

INTERMODULATION SPURIOUS ATTENUATION

AUDIO FREQUENCY RESPONSE

IF FILTER AND DISCRIMINATOR ALIGNMENT

USABLE SENSITIVITY

DETERMINE RF INPUT LEVEL WHICH PRODUCES ≥50% OF RATED OUTPUT WITH A 12 dB SINAD (EIA RECOMMENDATION)

TEST SETUP:

TEST PROCEDURE:
1. APPLY TEST SIGNAL MODULATED WITH 1 kHz TONE AT 2/3 MAXIMUM RATED DEVIATION.
2. SET GENERATOR OUTPUT LEVEL FOR ~ 1 MV AND ADJUST RECEIVER VOLUME CONTROL FOR MAX. RATED OUTPUT.
3. REDUCE RF INPUT SIGNAL UNTIL:
   a. SINAD = 12 dB
   b. AUDIO OUTPUT FALLS TO 50% OF RATED VALUE

   } WHICHEVER OCCURS FIRST

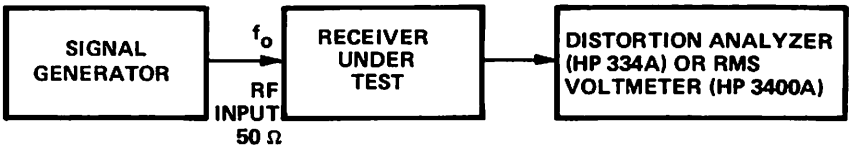
IMPORTANT SIG. GEN. SPECS:
ATTENUATION RANGE
ATTENUATION ACCURACY
LEAKAGE
FM DISTORTION

QUIETING SENSITIVITY

"QUIETING" → OUTPUT NOISE OF RECEIVER IS REDUCED AS UNMODULATED RF SIGNAL IS APPLIED.

QUIETING SENSITIVITY — RF INPUT LEVEL REQUIRED TO REDUCE NOISE OUTPUT BY 20 dB (EIA RECOMMENDATION)

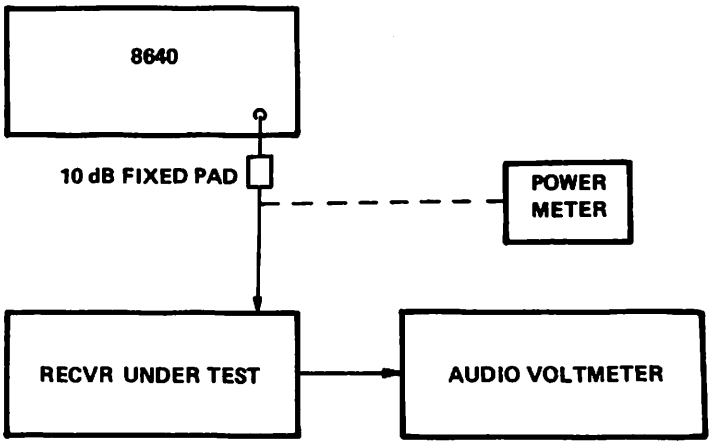
TEST SETUP:



TEST PROCEDURE:
1. APPLY UNMODULATED CARRIER AND ADJUST VOLUME CONTROL FOR NOISE OUTPUT EQUAL TO 25% OF RATED OUTPUT POWER.
2. INCREASE GENERATOR OUTPUT VOLTAGE UNTIL NOISE OUTPUT IS REDUCED BY 20 dB.

IMPORTANT SIG. GEN. SPECS
- ATTENUATOR RANGE
- ATTENUATOR ACCURACY
- LEAKAGE
- RESIDUAL FM

OUTPUT ACCURACY IMPROVEMENT PROCEDURE



PROCEDURE –1 ADJUST 8640 FOR PROPER RCVR SENSITIVITY CRITERION – READ LEVEL

–2) DISCONNECT RECVR AND CONNECT POWER METER

–3) INCREASE OUTPUT LEVEL RANGE ATTENUATOR TILL IN THE –7 dBm MAXIMUM SETTING

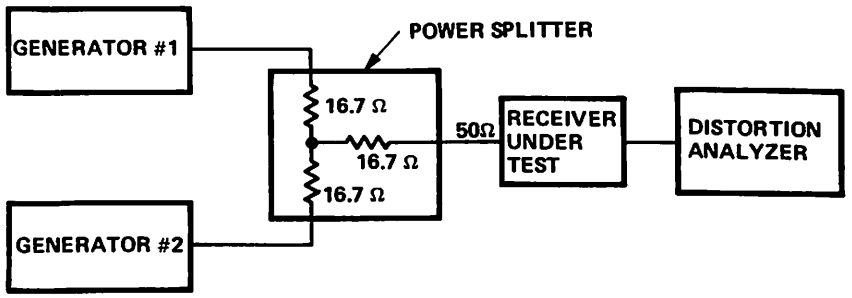
–4) READ POWER METER AND NOTE DIFFERENCE FROM 8640 LEVEL METER (MAGNITUDE AND SIGN)

–5) CORRECT READING IN NO. 1 BY VALUE FOUND IN NO. 4 — OVERAL ACCURACY IS THEN BETTER THAN ± 1 dB PLUS ± .25 dB ERROR DUE TO POWER METER

ADJACENT CHANNEL SELECTIVITY

MEASURE OF RECEIVER'S ABILITY TO DIFFERENTIATE BETWEEN A DESIRED MODULATION SIGNAL AND MODULATION SIGNALS ON ADJACENT CHANNELS

TEST SETUP

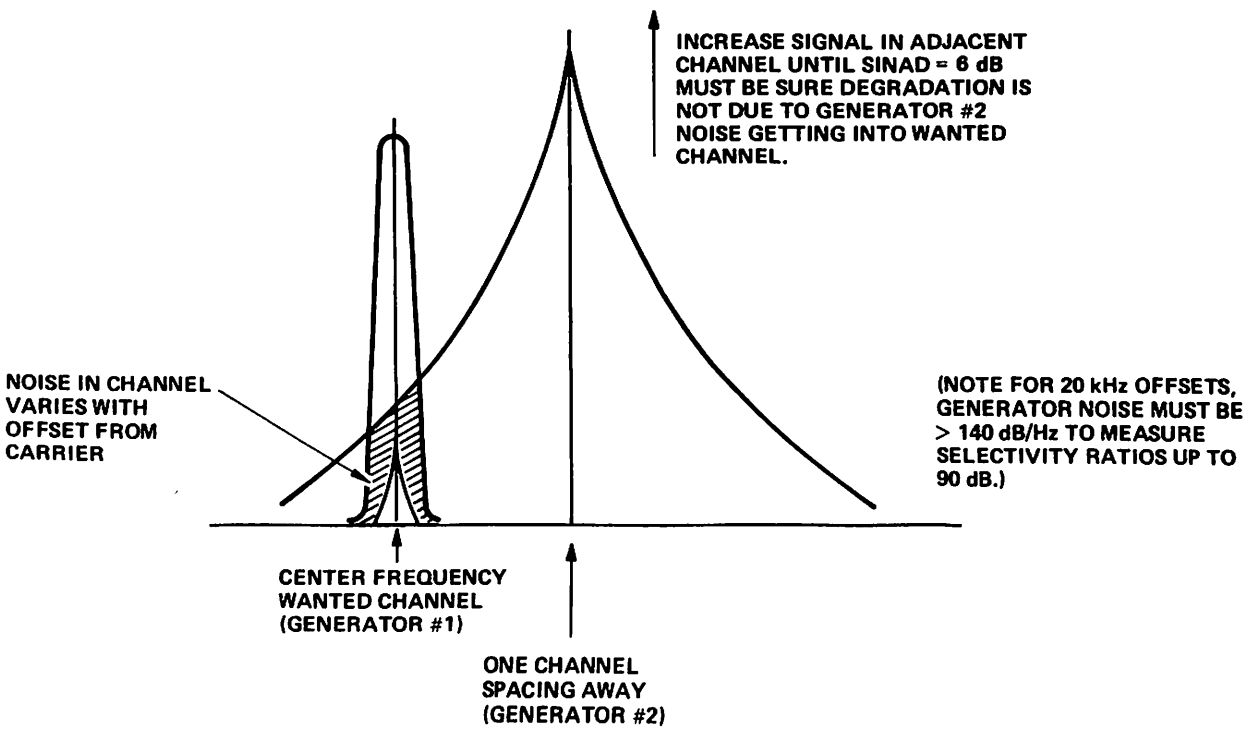


TEST PROCEDURE:

1. TURN GENERATOR #2 OFF, SET GENERATOR #1 TO f_o AND MODULATE WITH 1 kHz TONE AT 2/3 MAXIMUM RATED DEVIATION. SET LEVEL FOR 12 dB SINAD
2. TURN GENERATOR #2 ON AND MODULATE WITH 400 Hz TONE AT 2/3 MAX RATED DEVIATION.
3. TURN GENERATOR #2 TO ADJACENT CHANNEL AND ADJUST ITS LEVEL FOR 6 dB SINAD WITH DISTORTION ANALYZER NULLING 1000 Hz TONE.
4. RECORD RATIO OF GENERATOR #2 AMPLITUDE TO GENERATOR #1 AMPLITUDE.

IMPORTANT SIG. GEN. SPECS:
PHASE NOISE
SPURIOUS
FM DISTORTION
FREQUENCY STABILITY

IMPORTANCE OF SIGNAL GENERATOR PHASE NOISE IN ADJACENT CHANNEL TESTS:


INCREASE SIGNAL IN ADJACENT CHANNEL UNTIL SINAD = 6 dB MUST BE SURE DEGRADATION IS NOT DUE TO GENERATOR #2 NOISE GETTING INTO WANTED CHANNEL.
NOISE IN CHANNEL VARIES WITH OFFSET FROM CARRIER
(NOTE FOR 20 kHz OFFSETS, GENERATOR NOISE MUST BE > 140 dB/Hz TO MEASURE SELECTIVITY RATIOS UP TO 90 dB.)
CENTER FREQUENCY WANTED CHANNEL (GENERATOR #1)
ONE CHANNEL SPACING AWAY (GENERATOR #2)

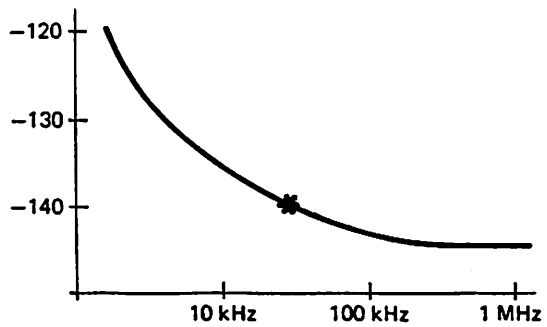
CALCULATION of SIGNAL GENERATOR PERFORMANCE for MEASURING RECEIVER SELECTIVITY

Receiver Spec	+	Conversion to 1 Hz BW from Rec'r Noise BW	+	Measurement Margin	=	Sig Gen Noise Spec. at 1 Channel offset in 1 Hz BW (Total Noise or SSB ϕ Noise)

EXAMPLE: 80 dB + 42 dB* + 6 dB = 128 dB below Carrier

* Conversion from 14 kHz BW to 1 Hz BW

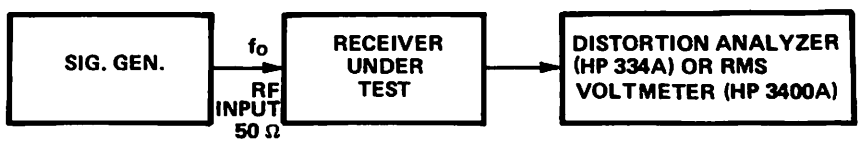
$$dB = 10 \log_{10} \frac{14\ kHz}{1\ Hz} \cong 10\ (4.2) = 42\ dB$$



SPURIOUS ATTENUATION

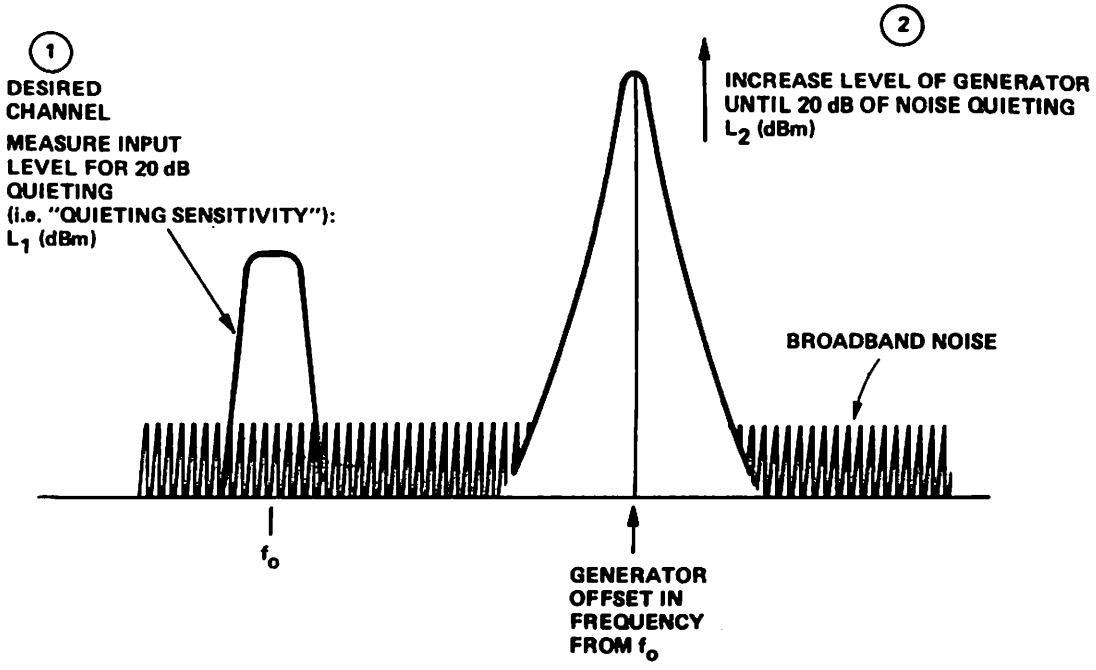
MEASURE OF RECEIVERS ABILITY TO DISCRIMINATE BETWEEN A DESIRED AND UNDESIRED SIGNAL. IF AND IMAGE FREQUENCIES SHOULD BE INCLUDED IN TEST.

TEST SETUP:



TEST PROCEDURE:
1. APPLY UNMODULATED SIGNAL TO RECEIVER AND ADJUST VOLUME CONTROL FOR NOISE OUTPUT = 25% RATED OUTPUT.
2. ADJUST GENERATOR OUTPUT FOR 20 DB QUIETING.
3. VARY GENERATOR FREQUENCY WHILE INCREASING OUTPUT LEVEL AND NOTE RESPONSES.
4. RATIO BETWEEN GENERATORS VOLTAGE FOR 20 DB QUIETING AT f_o AND VOLTAGE FOR 20 DB QUIETING AT A SPURIOUS FREQUENCY IS "SPURIOUS ATTENUATION"

IMPORTANT SIG. GEN. SPECS:
SPURIOUS
ATTENUATION RANGE
LEAKAGE
NOISE FLOOR
RF FREQUENCY RANGE


1
DESIRED CHANNEL
MEASURE INPUT LEVEL FOR 20 dB QUIETING (i.e. "QUIETING SENSITIVITY"): L_1 (dBm)
2
INCREASE LEVEL OF GENERATOR UNTIL 20 dB OF NOISE QUIETING L_2 (dBm)
BROADBAND NOISE
f_o
GENERATOR OFFSET IN FREQUENCY FROM f_o

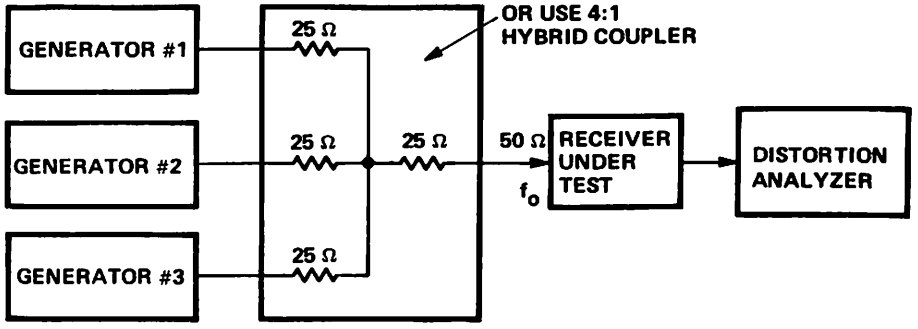
(3) SPURIOUS ATTENUATION [dB] = L_2 [dBm] – L_1 [dBm]

NOTE: WIDEBAND NOISE OF GENERATOR FALLS IN DESIRED CHANNEL. THIS NOISE LOOKS LIKE A SIGNAL AND WILL ALSO TEND TO QUIET THE RECEIVER.

INTERMODULATION SPURIOUS ATTENUATION

MEASURES ABILITY OF RECEIVER TO DISTINGUISH BETWEEN A DESIRED SIGNAL AND CERTAIN COMBINATIONS OF 2 OR MORE UNDESIRED SIGNALS AT OTHER FREQUENCIES.

TEST SETUP:

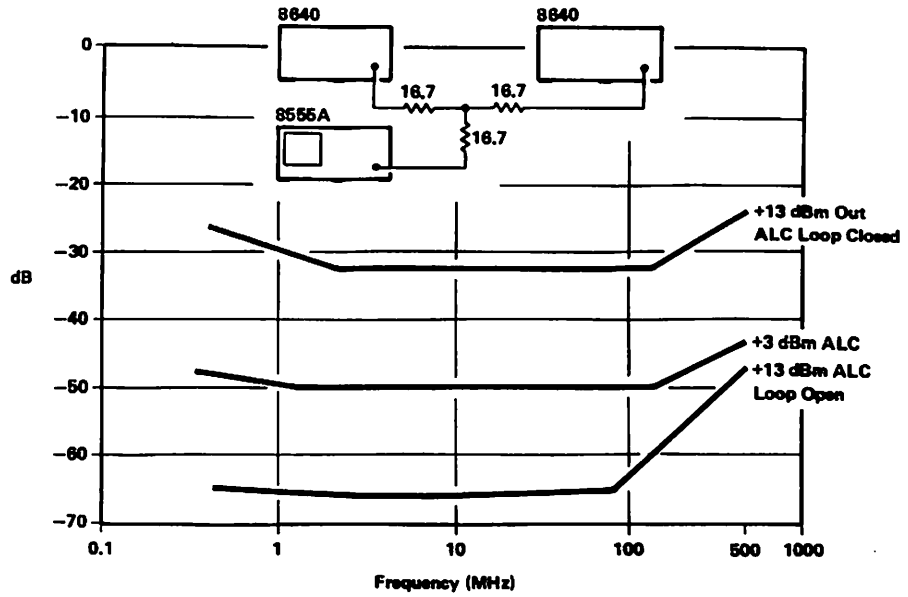


US method shown.
European method
uses
for a
dependable

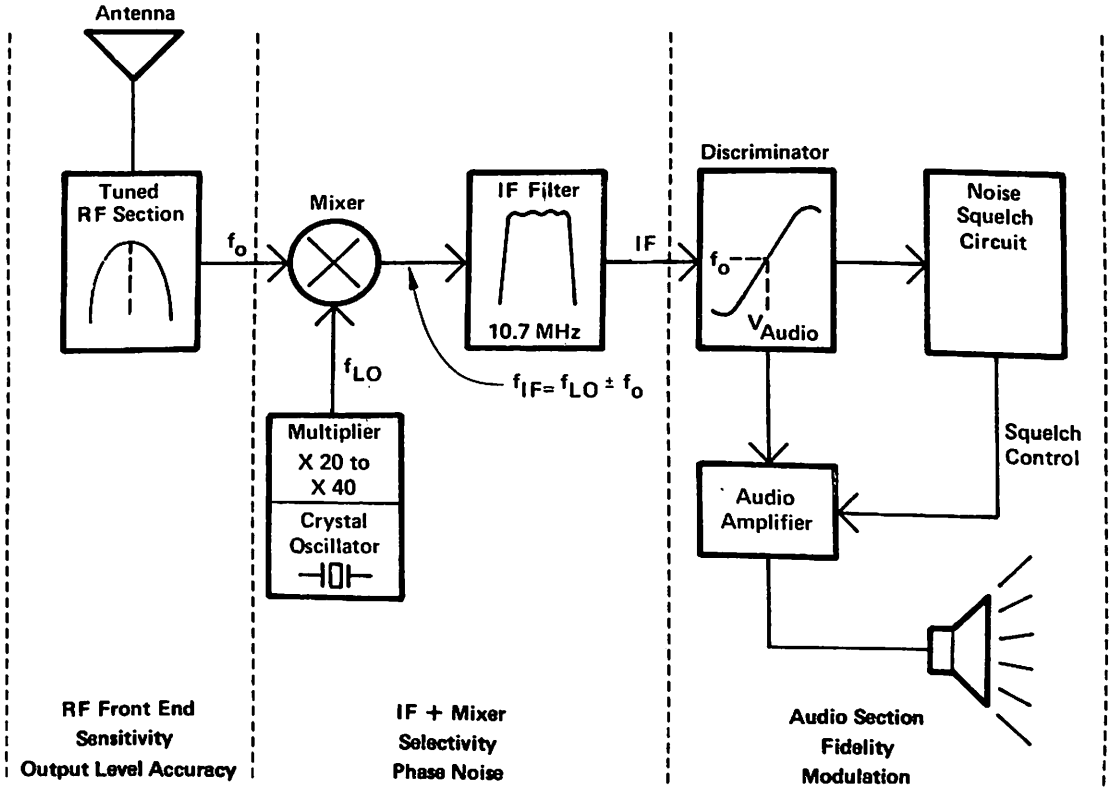
TEST PROCEDURE:
1. TUNE GENERATOR #1 TO f_o AND MODULATE WITH 1 kHz TONE AT 2/3 MAX RATED DEVIATION. ADJUST OUTPUT FOR 12 dB SINAD.
2. TUNE UNMODULATED GENERATOR #2 TO ADJACENT CHANNEL.
3. TUNE GENERATOR #3 TO NEXT ADJACENT CHANNEL WITH 400 Hz MODULATION AT 2/3 MAX. RATED DEVIATION.
4. INCREASE LEVELS OF #2 AND #3 EQUALLY UNTIL SINAD DEGRADES 6 dB. RATIO OF LEVEL OF GENERATOR #2 TO GENERATOR #1 IS INTERMOD ATTENUATION.

IMPORTANT SIG. GEN. SPECS:
PHASE NOISE
SPURIOUS
FM DISTORTION
INTERMODS FROM COUPLING 3 GENERATORS
FREQUENCY STABILITY

8640B TWO TONE TEST
(8640A/B 3rd Order 10 kHz Intermod Separation)

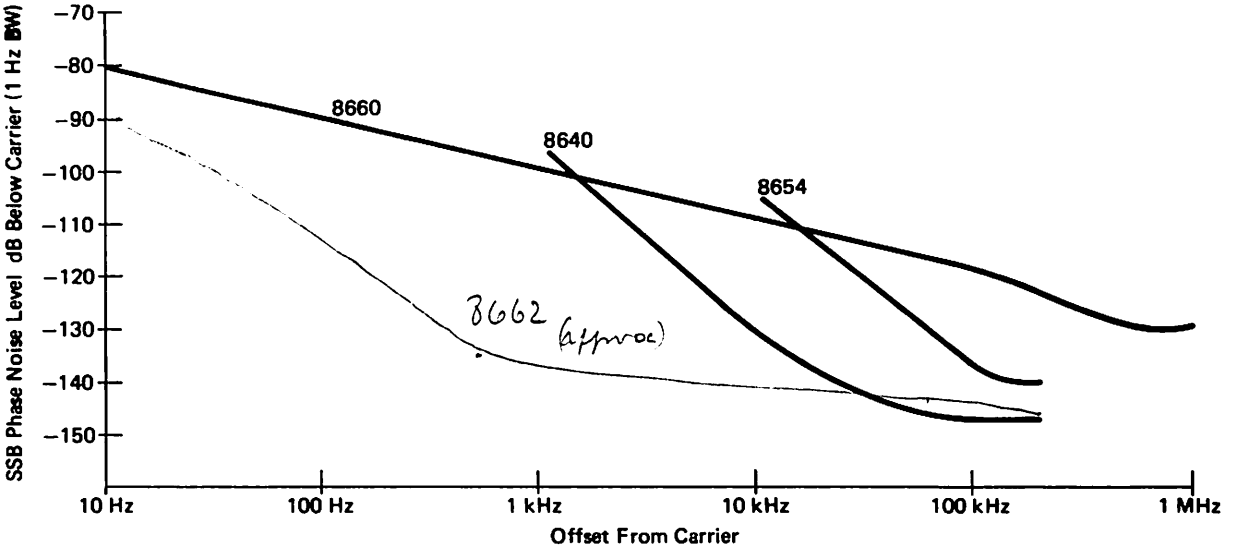


LAND MOBILE SIMPLIFIED FM RECEIVER

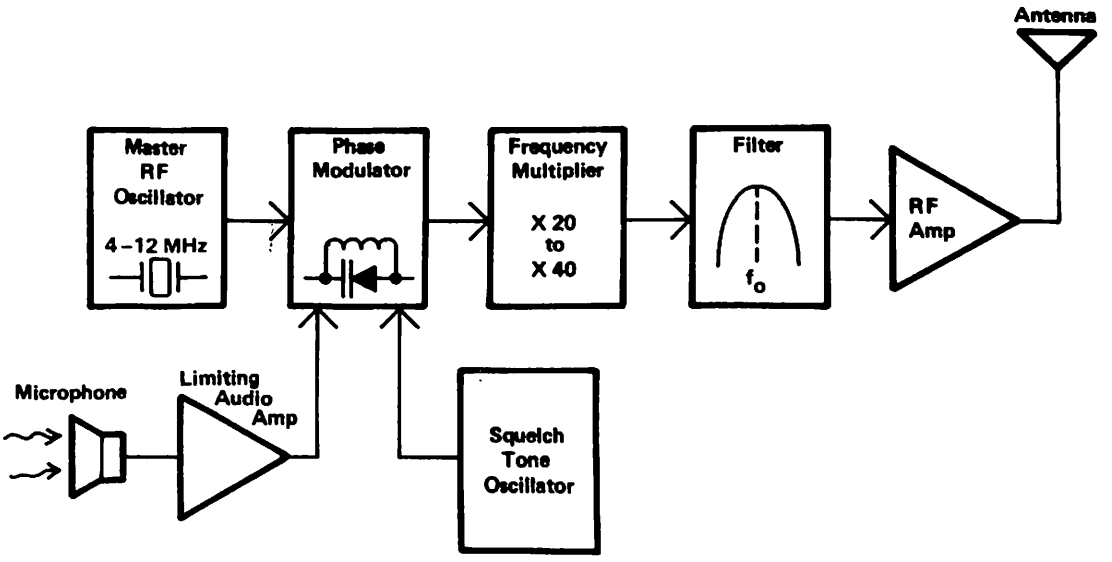


FM RECEIVER TEST	TYPICAL RADIO SPEC.	IMPORTANT SIG. GEN. SPECS.	SIG. GEN. SPEC REQUIRED	HP 8654B	HP 8660A/C	HP 8640B	HP 8662A
USABLE SENSITIVITY	.25 μV	Low Level Output	<–119 dBm	–130 dBm (0.07 μV)	–146 dBm (0.012 μV)	–145 dBm (0.013 μV)	–139.9 dBm (0.023 μV)
		Output Level Accuracy	As good as possible	± 3 dB (typically ±1.5 dB)	± 2 dB	±1.5 dB to ±2.5 dB (typically ±1.0 dB)	±1 dB (+13 to –120 dBm)
	3%	FM Distortion	<3%	<2%	<1%	<1% to 3%	<1% to <1.7%
	±50 ppm	Frequency Stability	Should not drift out of channel	<1 kHz + 20 ppm per 5 min.	±0.03 ppm/day	<0.05 ppm/hr.	Same as Reference Oscillator (Aging Rate $<5\times10^{-10}$/day)
		Leakage	<2.5 μV	0.5 μV	Meets Class B	MIL-I-6181D (<3 μV) (<1 μV special avail.)	MIL STD 461A (<1 μV)
ADJACENT CHANNEL SELECTIVITY	80 dB	Noise: SSB Φ Noise at 20 kHz offset in 1 Hz BW	>128 dBc in 1 Hz BW	126 dBc (typical)	–111 dBc	122 dBc to 140 dBc Function of Frequency (typically 144 dBc)	136 dBc (typical)
		Total Noise Floor	>128 dBc in 1 Hz BW	140 dBc (typical)	128 dBc (typical)	140 dBc (150 dBc typical)	150 dBc (typical)
		Spurious	>80 dBc	>100 dBc	80 dBc	>100 dBc	84 to >100 dBc
		Frequency Stability	Should not drift out of channel	<1 kHz + 20 ppm per 5 min.	± 0.03 ppm/day	< 0.05 ppm/hr.	Same as Reference Oscillator (Aging Rate $<5\times10^{-10}$/day)
SPURIOUS ATTENUATION	100 dB	Spurious	>100 dBc	>100 dBc	80 dBc	>100 dBc	84 to >100 dBc
		Attenuation Range	>100 dB	+ 10 dBm to –130 dBm (140 dB range)	+10 dBm to –146 dBm (156 dB range)	+19 dBm to –145 dBm (165 dB range)	+13 to –139.9 dBm (+16 dBm overrange)
		Noise Floor	>148 dBc	140 dBc (typical)	128 dBc	140 dBc (150 dBc typical)	150 dBc (typical)
		RF Frequency	$f_{sg} > f_{receiver} + 2\, f_{IF}$	10 to 520 MHz	1 to 1300 MHz	500 kHz to 512 MHz	10 kHz to 1280 MHz

COMPARISON OF PHASE NOISE
8660, 8640, 8654



FM MOBILE TRANSMITTER



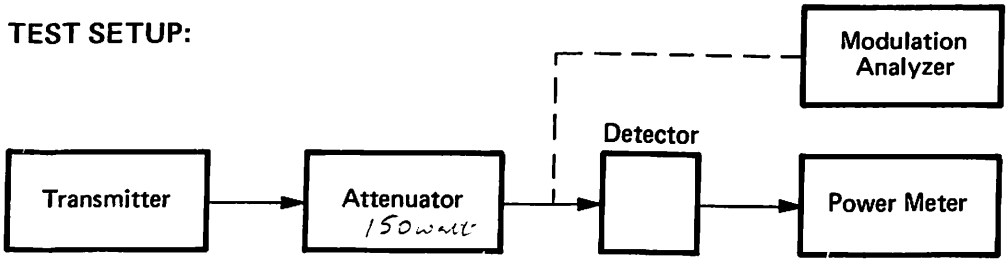
TYPICAL TRANSMITTER TESTS

Carrier power
Frequency error
Audio frequency response
Audio frequency distortion
Hum and noise
Microphone sensitivity
Modulation limiting
  Instantaneous
  Steady State
Sideband spectrum/spurious

CARRIER POWER OUTPUT RATING

Measure of power available at the output terminal of a properly terminated transmitter.

TEST SETUP:



8956 is a switching interface

TEST PROCEDURE:

1. Key transmitter without modulation.
2. Record Power Meter results and adjust for insertion loss of attenuators and test fixtures.

or

1. Key transmitter without modulation.
2. Read power with modulation analyzer in RF LEVEL mode and adjust for insertion loss of attenuators and test fixtures.

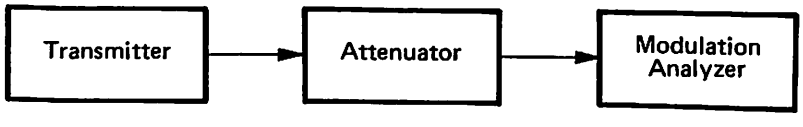
IMPORTANT INSTRUMENT SPECIFICATION

SWR of attenuation and detector accuracy of detector/power meter or modulation analyzer.

FREQUENCY ERROR

Measure frequency error from the assigned transmitter carrier frequency.

TEST SETUP:



TEST PROCEDURE:

1. Key transmitter
2. Key in assigned transmitter and put modulation analyzer in FREQ. ERROR mode.

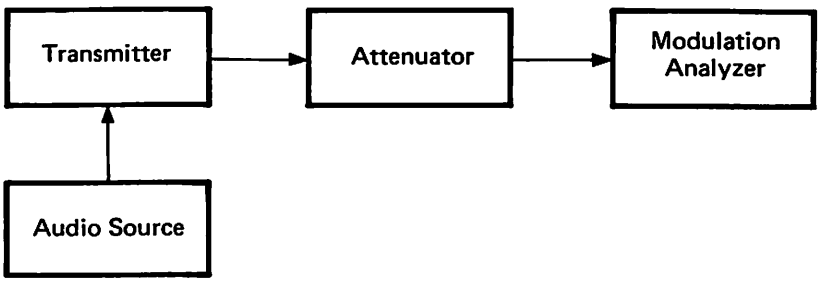
IMPORTANT INSTRUMENT SPECIFICATION:

Counter resolution, accuracy, time base stability.

AUDIO FREQUENCY RESPONSE

Measure degree of closeness of transmitter frequency deviation to a prescribed characteristic.

TEST SETUP



FM TRANSMITTERS TEST PROCEDURE:

1. Operate the transmitter with a sinewave input.
2. Vary the input audio frequency and observe the input level necessary to maintain a constant 30% system deviation.
3. Compare input level measured in step 2 at each frequency point with pre-emphasis characteristic (6 dB/octave from 300 Hz to 3 kHz rate using 1 kHz reference).

or

1. Operate the transmitter with a sinewave input.
2. Adjust audio level at 1 kHz rate until modulation analyzer indicates 25% system deivation. Then put modulation analyzer in PRE-DISPLAY dB ratio mode.
3. Modulation analyzer indicates audio flatness directly in dB as audio frequency is varied.

AM TRANSMITTERS TEST PROCEDURE:

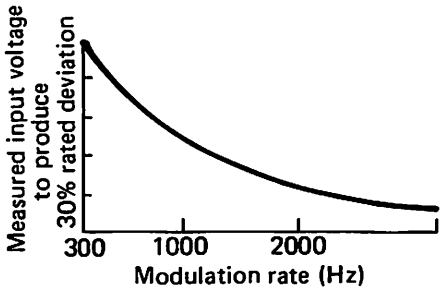
1. Operate the transmitter with a sinewave input.
2. Adjust audio level for 30% AM depth at 1 kHz & put modulation analyzer in relative dB ratio mode.
3. Modulation analyzer indicates audio flatness directly in dB as audio frequency is varied.

IMPORTANT INSTRUMENT SPECIFICATION

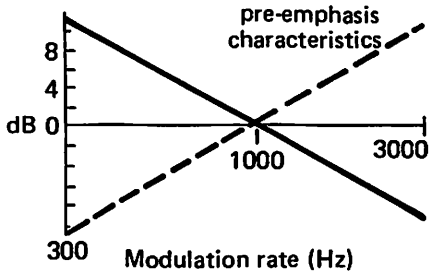
Audio Source — flatness
Modulation Analyzer — modulation flatness

FM TRANSMITTER AUDIO FREQUENCY RESPONSE

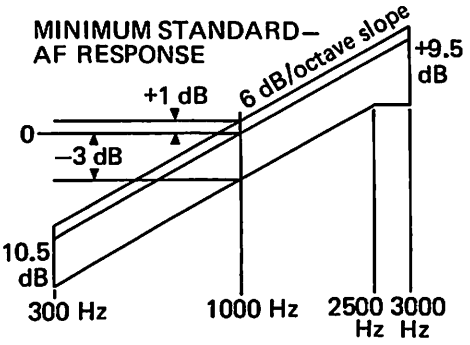
Present Method:



1. Measure and record audio input voltage required to produce 30% rated deviation at discrete frequencies between 300 Hz and 3 kHz.

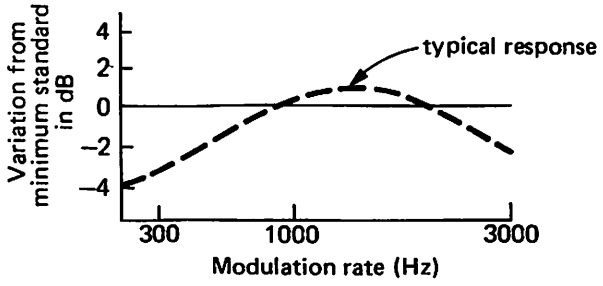


2. Convert voltage data to dB using the 1 kHz point as the reference. Invert the line about the 1 kHz point. (This corresponds to the curve which would result if level is held constant and frequency varied).



3. Compare the pre-emphasis characteristic (dotted line in step 2) with minimum standard at each data point.

With 3901A:



1. Adjust audio level at 1 kHz for 25% rated deviation. Then set up the analyzer for 750 μs, PRE-DISPLAY, and dB ratio mode. The 8901A display will indicate the flatness in dB.

7. AUDIO FREQUENCY RESPONSE*

7.1 Definition – The term "audio frequency response' denotes the degree of closeness to which the frequency deviation of the transmitter follows a prescribed characteristic.

7.2 Minimum Standard – (Refer to Figure 1)
From 300–3000 Hz the audio frequency response shall not vary more than +1 or –3 dB from a true 6 dB per octave pre-emphasis characteristic as referred to the 1000 Hz level (with the exception of a permissible 6 dB per octave roll-off from 2500 to 3000 Hz).

Above 3000 Hz the audio response shall be –

a) 25–450 MHz – Attenuated greater than that obtained by a 6 dB per octave de-emphasis line extended from the 3 kHz point to 15 kHz, and a 6 dB per octave pre-emphasis line extended from the 15 kHz point to 30 kHz.

b) 450–470 MHz – Attenuated greater than that obtained by a 12 dB per octave de-emphasis line extended from the 3 kHz point to 20 kHz, and a 6 dB per octave pre-emphasis line extended from the 20 kHz point to 30 kHz.

7.3 Method of Measurement – Operate the transmitter under standard test conditions except as per section 2.24 and monitor the output with a frequency deviation meter or a calibrated test receiver. With a sine wave audio input (applied through the dummy microphone circuit specified by the manufacturer), vary the modulating frequency from 300 to 3000 Hz and observe the input levels necessary to maintain a constant 30% system deviation.

Adjust the audio input frequency to 100 Hz and the input level to 20 dB greater than that required to produce standard test modulation. Note the output level on the frequency deviation meter or a calibrated test receiver. Using this output level as reference (0 dB), vary the modulating frequency from 3000 Hz to 30,000 Hz and observe the change in output while maintaining a constant input level.

*Extracted from EIA Standard RS-152B

AUDIO FREQUENCY DISTORTION

Measure of transmitter audio distortion.

TEST SETUP

TEST PROCEDURE:

1. Key transmitter and set audio source to frequency at which distortion is to be measured (usually 1 kHz).
2. Adjust audio level until modulation analyzer indicates 30% or 60% rated FM deviation.
3. Measure distortion of the demodulated audio signal at the MODULATION OUTPUT.

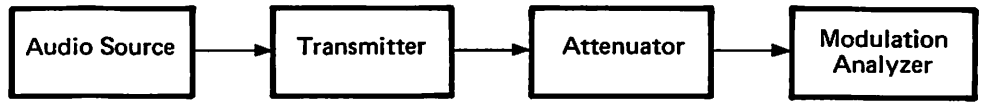
IMPORTANT INSTRUMENT SPECIFICATION:

1. Audio Source – low distortion.
2. Modulation Analyzer – low distortion of Modulation Output.

HUM AND NOISE

Measure of residual modulation, usually expressed as a dB ratio to normal test modulation.

TEST SETUP:



TEST PROCEDURE:

1. Key transmitter and adjust audio source level until modulation analyzer indicates 60% rated deviation (or 30% AM).
2. Put the modulation analyzer in dB ratio mode and remove the modulation signal and read the FM (or AM) Hum and Noise from the modulation analyzer display.

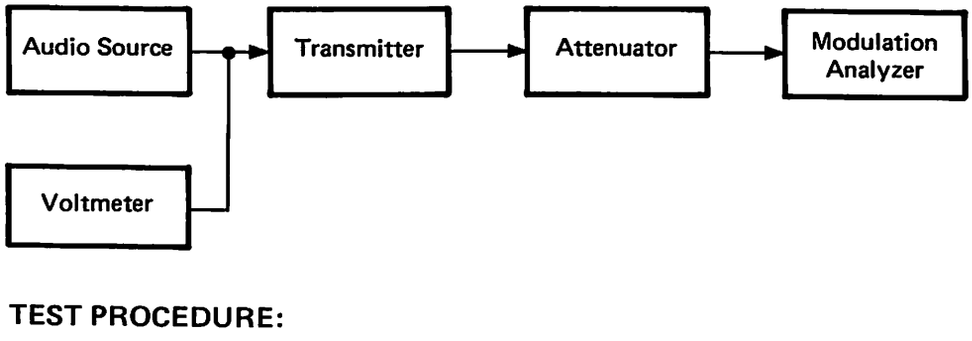
IMPORTANT INSTRUMENT SPECIFICATION

Residual FM and Residual AM of modulation analyzer.

MICROPHONE SENSITIVITY

Measure of audio level at microphone input required to produce standard test modulation.

TEST SETUP



TEST PROCEDURE:

1. Key transmitter and adjust audio source level until modulation analyzer indicates 60% rated deviation (30% AM).
2. Measure the audio source output level with the voltmeter and record the result.

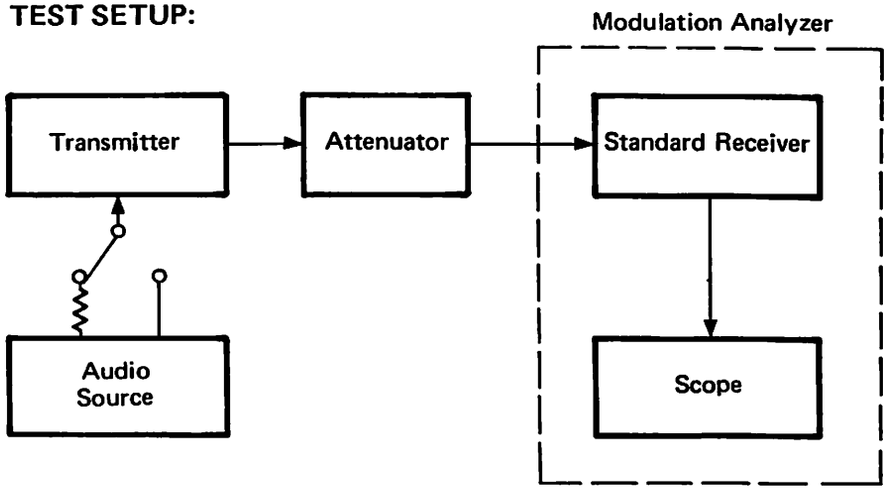
IMPORTANT INSTRUMENT SPECIFICATION:

Modulation analyzer accuracy, voltmeter accuracy, audio source output level range (to ≈ -70 dBm).

MODULATION LIMITING

Measure maximum deviation attainable to assure transmitter does not exceed rated deviation limits.

TEST SETUP:



TEST PROCEDURE:

1. Set up system for 60% of rated deviation.
2. Increase audio level 20 dB in one step.
3. Measure the instantaneous and long term deviation response, using a calibrated storage oscilloscope.

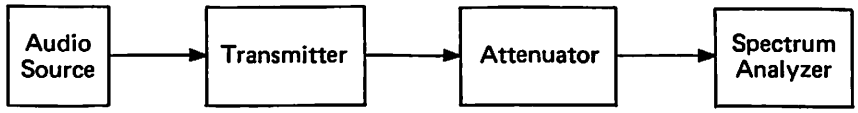
   Note: If the standard receiver is a modulation analyzer instantaneous and steady state limiting can be measured directly without using a storage oscilloscope by placing the analyzer in PEAK HOLD mode after step 1. Steady state limiting is measured by taking modulation out of PEAK HOLD mode.

IMPORTANT INSTRUMENT SPECIFICATION:

Modulation analyzer — transient response.

SIDEBAND SPECTRUM/SPURIOUS

TEST SETUP:



TEST PROCEDURE:

1. Key transmitter and adjust audio to 2500 Hz, 16 dB greater than the level required to produce 50% rated deviation (50% AM) at 1000 Hz.
2. Measure levels of transmitter sideband and spurious signals. The permissible level for these signals relative to the carrier (dBc) is:

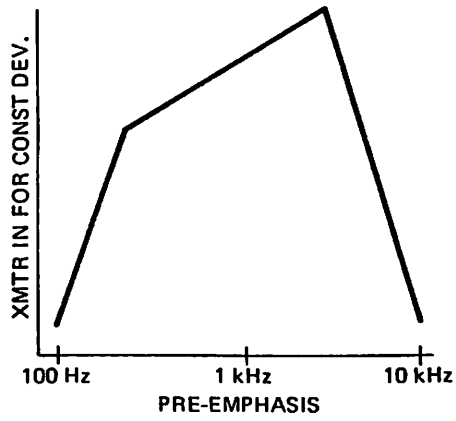
Minimum Performance	Frequency Offset from Carrier in % of Authorized Bandwidth
−25 dBc	> 50%
−35 dBc	> 100%
$-[43 + 10 \log_{10}$ (Power output in watts)]	> 250%

IMPORTANT INSTRUMENT SPECIFICATION:

Spectrum Analyzer — spurious free dynamic range
— accuracy

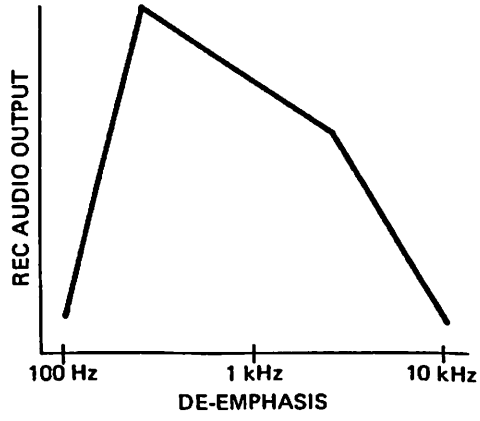
PRE-EMPHASIS/DE-EMPHASIS

TRANSMITTER FREQ RESPONSE



Pre-Emphasis:
Provides a constant modulation index vs. modulation rate.

RECEIVER FREQ RESPONSE



De-Emphasis:
Removes pre-emphasis from de-modulated audio signal in a receiver.

8950B CAPABILITIES

Transmitter Tests

Carrier Power
Carrier Frequency and Stability
AM Depth
Peak FM Deviation
Audio Distortion
Audio Response
Audio Sensitivity
Continuous Squelch Tone Frequency
Limited Spurious Measurement (<40 dBc)
Power Supply Sensitivity
Current Drain

Receiver Tests

SINAD Sensitivity
Quieting Sensitivity
Squelch Threshold
Audio Power
Audio Distortion
Audio Response
AGC Response
Modulation Acceptance Bandwidth
Power Supply Sensitivity
Current Drain

Module and Subassembly Test

DC Voltage
AC Voltage
Resistance
Frequency

ADVANTAGES OF AUTOMATION

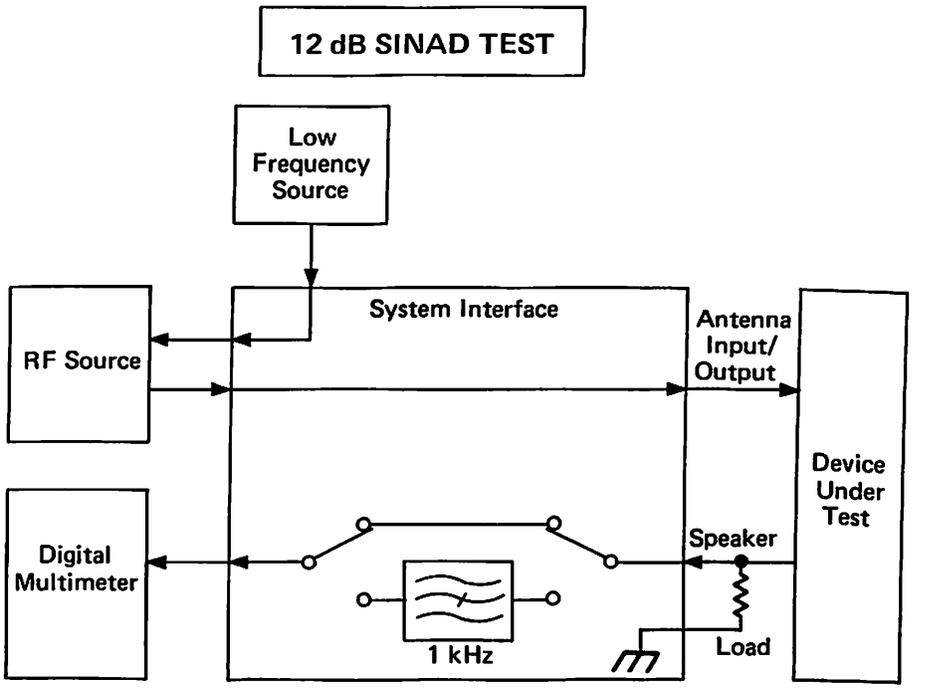
- Speed
- Accuracy
- Repeatability
- Flexibility
- Data Presentation
- Reduced Training Needs

HP SUPPLIED SOFTWARE

1. Inst Drivers and Measurement Subroutines
2. Verification Programs
3. Calibration Program
4. Example Transceiver Test Program

USER SUPPLIED SOFTWARE

1. Programming to Link Subroutines
2. Data I/O Statements
3. Any Special Test Subroutines



8950B PROGRAMMING

Step 1. Decide what tests you wish to perform.

Step 2. Set up all necessary preconditions.

Step 3. Make the transceiver measurement.

Step 4. Output the test results.

8950B APPLICATIONS

Transceiver Manufacturers

Production Test
Quality Control
Research and Development
Calibration Labs

Transceiver Users

Acceptance Testing
Maintenance
Incoming Inspection

NEW SPECIAL OPTIONS

J10: +$5655

Substitute the 8662A for the standard 8660 system.

- Provide 0.1 dB output level resolution (better repeatabiltiy on sensitivity measurements)

J14: +$8420

Add the 8901A Modulation Analyzer (includes rear panel connectors and calibrators

Provides:

- 1% of reading accuracy for modulation measurements
- Measurement of incidental AM and FM
- Measurement of residual AM and FM
- Instantaneous peak FM modulation limiting

SIGNAL GENERATOR CALIBRATION USING THE 8901A

This is an important application for the 8901A Modulation Analyzer. It greatly reduces the time and equipment required to verify the modulation calibration of signal generators. This paper will contrast the old method of measuring signal generator specifications found in the 8640B manual with the new procedures resulting from the capabilities of the 8901A. The specifications involved are:

A. Residual AM
B. AM Bandwidth
C. AM Distortion
D. AM Sensitivity and Accuracy
E. Incidental ΦM (or FM)
F. Residual FM
G. FM Bandwidth (with calibration)
H. FM Distortion
I. FM Sensitivity and Accuracy
J. Incidental AM

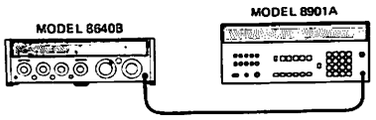
For each specification the old method is illustrated on the right side of the page while the new procedures using the 8901A are on the left side. Note that only abbreviated procedures are given. In addition, the 8901A can be used to indicate proper operation of the following parameters:

K. Counter Accuracy
L. RF Level Accuracy
M. Harmonic Distortion

The 8901A SPECIAL FUNCTIONS, like 4.1 spec., are discusssed on the 8901A pull-out card and can be used to further simplify certain measurements.

A. RESIDUAL AM

Equipment:

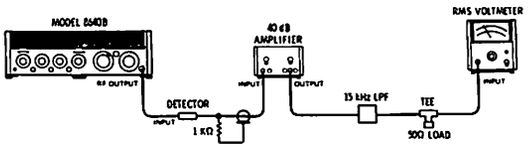


8901A Modulation Analyzer

TIME: 2 minutes

PROCEDURE: Turn-off 8640 modulation, connect 8901A to 8640; select AM measurement, 15 kHz low-pass filter, average detector. Enter 100, then dB ratio to make reading relative to carrier power (100% AM = 0 dB). (Spec −78 dB.) Select 300 Hz high-pass, 3 kHz low-pass filters. Error "E11" indicates a reading of 0.00% residual AM or −∞ dB. (Spec. −85 dB.)

Equipment:



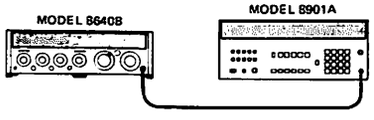
3400A Voltmeter
8471A Crystal Detector
15 kHz Low-Pass Filter
465A Amplifier
11593A 50Ω Load
1 kΩ Resistor

TIME: 15 minutes.

PROCEDURE: Connect equipment as shown. Set 8640 to 10% AM. Note reading on voltmeter. Turn-off AM; residual reading must be 58 dB below reference since 10% AM is 20 dB down from carrier (double sideband). Cannot measure 300 to 3 kHz with this procedure.

B. AM BANDWIDTH

Equipment:



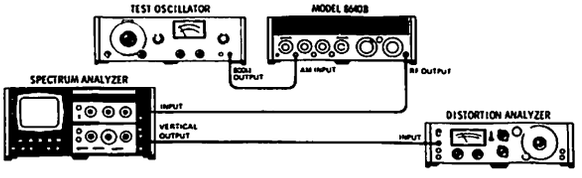
8901A Modulation Analyzer
Audio Source*

TIME: 5 minutes.

PROCEDURE: Connect equipment as shown. Set 8640 to 50% AM at 1 kHz rate. Select 8901A AM measurement, no filters, ±peak detector, then depress dB ratio. Vary the audio oscillator and determine the 3 dB modulation rate. (Spec 20 kHz to 60 kHz depending on carrier frequency). Set 8640 to 90% at 1 kHz rate. Place 8901A in dB ratio mode. Vary modulation rate. (Spec 12.5 kHz to 50 kHz).

*Use internal 8640 oscillator as example.

Equipment:



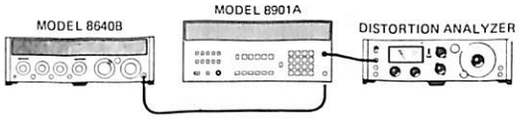
8554A Spectrum Analyzer System
331A Distortion Analyzer
651B Test Oscillator

TIME: 15 minutes.

PROCEDURE: Connect equipment as shown. Externally modulate the 8640 using the test oscillator at 50% or 90%. The AM is demodulated with the spectrum analyzer in zero scan mode and display scale to linear. The demodulated AM, available at the analyzer's vertical output, is measured with a distortion analyzer which is used as an adjustable voltmeter. As the test oscillator frequency is increased, the decrease in AM depth is noted. Each time a new carrier frequency is measured the spectrum analyzer must be re-adjusted.

C. AM DISTORTION

Equipment:

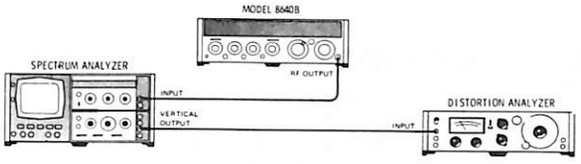


8901A Modulation Analyzer
Distortion Analyzer

TIME: 5 minutes.

PROCEDURE: Connect equipment as shown. Set 8640 to desired AM depth using the internal oscillator. Measure distortion. Spec. for carrier frequencies <512 MHz: 0–50% AM, <1%; 50–90% AM, <3%. For carrier frequencies >512 MHz: 0–50% AM, <10%; 50–90% AM, <20%.

Equipment:



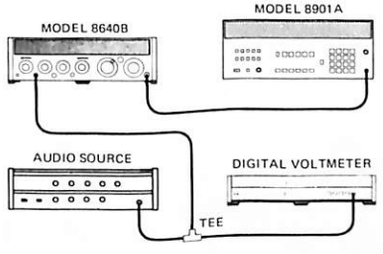
8554B Spectrum Analyzer System
331A Distortion Analyzer

TIME: 15 minutes.

PROCEDURE: Connect equipment as shown. Set the 8640 to desired AM depth using the internal oscillator. The AM is demodulated by the spectrum analyzer and distortion is measured at the analyzer's vertical output. Set the spectrum analyzer to 300 kHz or greater bandwidth, vertical scale to linear, display smoothing to 10 kHz. Adjust controls to center the display; set to zero scan; tune to peak the display. Measure distortion. Each time a new carrier frequency is measured, the spectrum analyzer must be re-adjusted.

D. AM SENSITIVITY AND ACCURACY

Equipment:



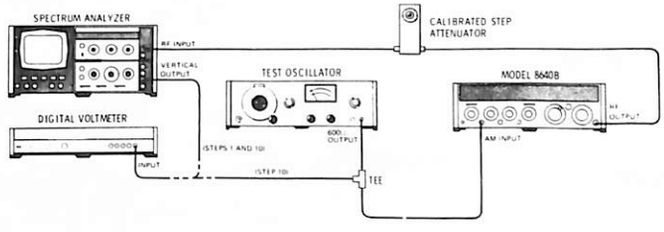
8901A Modulation Analyzer
Audio Synthesizer*
Digital Voltmeter*

TIME: 5 minutes.

PROCEDURE: To measure indicated AM accuracy connect 8901A to 8640. Using the internal 8640 audio oscillator at 400 Hz and 1 kHz rates, set various AM depths on 8640 and read accuracy on 8901A by entering the same depth on the keyboard and then % ratio key. (Spec. ±5.5% of reading ±1.5% of full scale for carrier frequency <512 MHz). To measure sensitivity connect equipment as shown. Set 8640 to external AC, AM vernier fully cw. By setting the input voltage to various readings, the resulting AM depth can be monitored on the 8901A. (Spec. 0.1% ±0.005% per mV peak for carriers <512 MHz.)

*Only required when making sensitivity measurement.

Equipment:



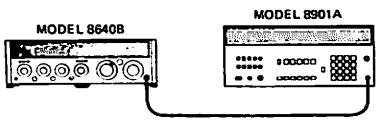
8554B Spectrum Analyzer System
3490A Digital Voltmeter
651A Test Oscillator
355D Step Attenuator

TIME: 45 minutes.

PROCEDURE: Connect the equipment as shown. Set spectrum analyzer to 20 kHz/div., scale to linear, center the display. Set frequency span per division to 0 Hz. The spectrum analyzer's detector must now be calibrated so that it can be used to measure AM percentage. This is done by measuring the ac and dc voltages at the analyzer's vertical output and adjusting the reference level for a given dc level. The dc off-set of the detector is then calculated and the detector calibrated. Sensitivity and accuracy may now be measured. The spectrum analyzer must be periodically re-adjusted because of drift and re-calibrated for each new frequency.

E. INCIDENTAL PHASE MODULATION (& FM)

Equipment:

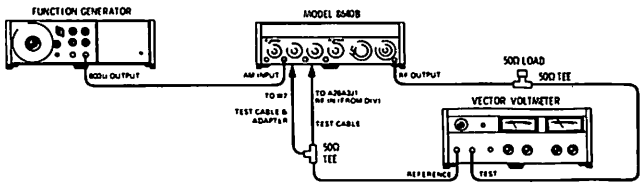


8901A Modulation Analyzer

TIME: 2 minutes.

PROCEDURE: Connect the 8901A to the 8640. Set 8640 to 1 kHz rate 30% AM depth. Set 8901A to ΦM measurement and 50 Hz high-pass (automatically inserted when ΦM selected). Measure incidental ΦM. (Spec. 0.5—128 MHz, <0.15 rad; 128—512 MHz, <0.3 rad.; 512—1024 MHz, <0.6 rad.) Peak incidental FM can be measured by selecting 50 Hz and 15 kHz filters, FM measurement. (Spec. peak incidental ΦM x modulation rate.)

Equipment:



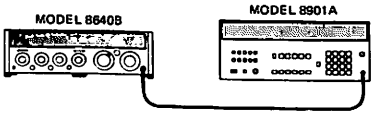
3300A Function Generator
8405A Vector Voltmeter

TIME: 90 minutes.

PROCEDURE: Disconnect 8640 from power line, remove bottom cover. Remove semi-rigid coaxial cable W7 from jack A26W3J1 labeled RF IN (FROM DIV). Connect one test cable to A26W3 and another to W7. Connect equipment as shown. Allow one hour warm-up before continuing. Set function generator to 1 kHz sine wave and adjust 8640 to 30% AM. Set function generator for 0.1 Hz rate. Set 8640 AM switch to dc. Monitor peak-to-peak phase deviation on vector voltmeter. This cannot measure specification at specified rates (8405 will not respond). Peak FM can be calculated but only for 0.1 Hz rates.

F. RESIDUAL FM

Equipment:

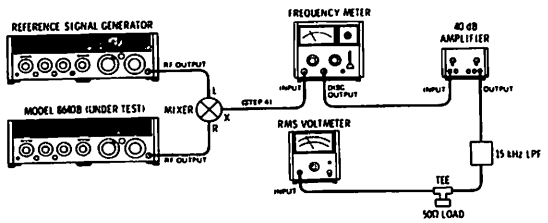


8901A Modulation Analyzer

TIME: 2 minutes.

PROCEDURE: Turn 8640 AM to off, FM to AC, vernier fully cw. Connect 8901A to 8640; select FM measurement, 15 kHz low-pass filter, average detector. Read residual FM. (Spec. <15 Hz, 256 to 512 MHz; <30 Hz, 512 MHz to 1024). Select 300 Hz high-pass, 3 kHz low-pass filters. (Spec. <5 Hz, 256 to 512 MHz; <10 Hz, 512 MHz to 1024 MHz).

Equipment:



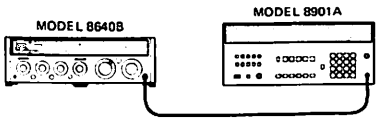
5210A Frequency Meter
10531A Filter Kit
3400A Voltmeter
465A Amplifier
8640A Signal Generator
10514A Mixer
15 kHz Low-Pass Filter
11593A 50Ω Load

TIME: 15 minutes.

PROCEDURE: Connect equipment as shown. Turn 8640 AM off, FM to AC, vernier fully cw. Set second 8640 to 100 kHz lower in frequency than the one under test. Check calibration by modulating 8640. Turn-off modulation, calculate residual FM. Procedure does not measure 300 Hz to 3 kHz specification.

G. FM BANDWIDTH

Equipment:



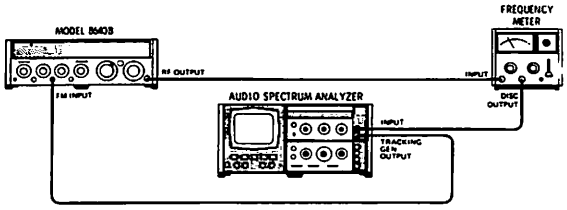
8901A Modulation Analyzer
11715A AM-FM Test Accessory*
Audio Synthesizer*

TIME: 10 minutes, including calibration time.

PROCEDURE: Calibrate the 8901A to 250 kHz rates; record data. Connect 8901A to 8640; set 8901A to FM measurement, no filters. Connect 8901A to 8640. Set 8640 to 80 kHz peak FM deviation. Vary the modulation rate between 20 Hz and 250 kHz. Determine variations using calibration data. (Spec. <3 dB between 20 Hz and 250 kHz).

*The 8901A is specified to 200 kHz rates. The 8640's 3 dB bandwidth is 250 kHz. The 11715A and audio synthesizer are required to calibrate the 8901A at higher rates before making this measurement.

Equipment:



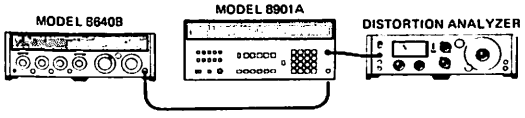
8556A Audio Spectrum Analyzer System
5210A Frequency Meter
10531A Filter Kit

TIME: 30 minutes.

PROCEDURE: Connect equipment as shown. Prepare 1 MHz Butterworth low-pass filter and insert in 5210A. Set 8640 to 80 kHz FM deviation. Sweep 8556A up to 250 kHz; monitor variations on display. Note: the 5210's incidental AM rejection may be insufficient and cause 8640 to appear out of specification. This needs to be checked and sensitivity and trigger level adjusted accordingly.

H. FM DISTORTION

Equipment:

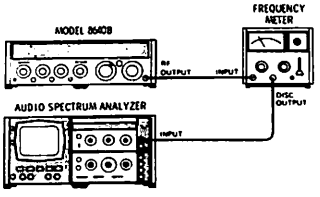


8901A Modulation Analyzer
Distortion Analyzer

TIME: 5 minutes.

PROCEDURE: Connect equipment as shown. Set 8640 to internal FM modulation at 400 Hz or 1 kHz rate. Set 8901A to FM measurements, no filters. Monitor distortion on the distortion analyzer. (Spec. <1% for deviations up to 1/8 allowed. <3% up to maximum allowable deviation).

Equipment:



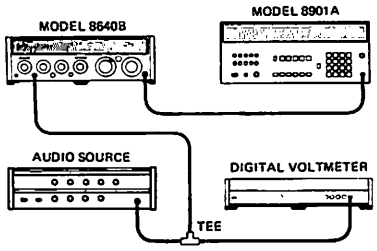
5210A Frequency Meter
10531A Filter Kit
8556A Audio Spectrum Analyzer System

TIME: 15 minutes.

PROCEDURE: Connect equipment as shown. Install 1 MHz Butterworth filter in 5210A. Set 8640 to 8 MHz frequency. Set deviation to 80 kHz. Monitor distortion sidebands on spectrum analyzer.

I. FM SENSITIVITY AND ACCURACY

Equipment:



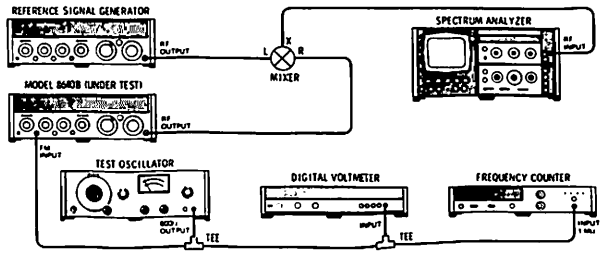
8901A Modulation Analyzer
Audio Synthesizer*
Digital Voltmeter*

TIME: 10 minutes.

PROCEDURE: To measure indicated AM accuracy, connect 8901A to 8640. Using the internal 8640 audio oscillator at 400 Hz and 1 kHz set various FM deviations. Read accuracy on 8901A by entering the same deviation on the keyboard and the % ratio key. (Spec . ±10% of reading). To measure sensitivity connect equipment as shown. Set 8640 to EXT AC, FM vernier fully cw. 1 volt yields full scale deviation. Set various voltages, measure deviation (Spec. accuracy ±6% excluding maximum deviation setting).

*Only required when making sensitivity measurements.

Equipment:



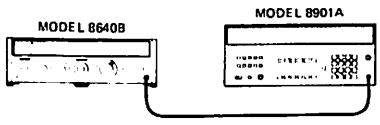
651B Test Oscillator
3490A Digital Voltmeter
5327C Frequency Counter
8554B Spectrum Analyzer System
8640A Signal Generator
10514A Mixer

TIME: 45 minutes.

PROCEDURE: The 8640's FM sensitivity is checked using the carrier (Bessel) null technique. An externally applied 2.079 kHz signal is used to FM the generator. The modulation signal amplitude is adjusted for a first order null which results in 5 kHz peak deviation. Various carrier frequencies are tested by re-setting both 8640's. This tests only one deviation (5 kHz) and does not check at specified 400 Hz and 1 kHz rates.

J. INCIDENTAL AM

Equipment:

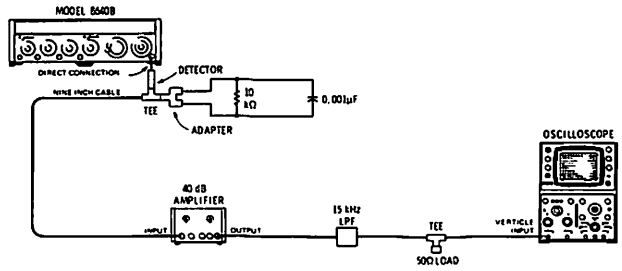


8901A Modulation Analyzer

TIME: 2 minutes.

PROCEDURE: Connect 8640 to 8901A. Set 8640 to INT 400 Hz or 1 kHz FM modulation. Set 8901A to AM measurement using the average detector. (Spec. <0.5% up to 1/8 max. allowable deviation for carrier frequency <512 MHz. Above 512 MHz <1%).

Equipment:



423A Crystal Detector
15 kHz Low-Pass Filter
465A Amplifier
180A Oscilloscope
0.001 μF Capacitor
10kΩ Resistor

TIME: 15 minutes.

PROCEDURE: An audio signal is used to amplitude modulate the 8640. The resulting modulated RF is detected and used to calibrate an oscilloscope. The 8640 is then frequency modulated and any incidental AM measured on the oscilloscope. Detector must be placed directly on 8640 output or SWR reflections will cause apparent incidental AM. The resistor and capacitor load must be varied depending on carrier frequency.

GENERAL MODULATION MEASUREMENTS
COMMENTS

Equipment Required for all Previous Tests:

8901A Modulation Analyzer
Audio Synthesizer
Digital Voltmeter
Distortion Analyzer
11715A AM-FM Test Accessory

Total Time to Make all Listed Measurements:
48 minutes.

Comments

All measurements can be made with one basic instrument set-up. If an automatic distortion analyzer were available all tests could be automated. Many measurements that are made at single modulation rates are just as easily made at all others. Using 4.1 spec (auto tune-track), most 8640 modulation parameters can quickly be measured over a complete RF frequency band.

Equipment Required for all Previous Tests:

3400 Voltmeter
8471A Crystal Detector
15 kHz Low-Pass Filter
465A Amplifier
11593A 50Ω Load
1 kΩ Resistor
5210A Frequency Meter
10531A Filter Kit
8640A Signal Generator
10514A Mixer
651A Test Oscillator
3490A Digital Voltmeter
5327C Frequency Counter
8554B Spectrum Analyzer System
355D Step Attenuator
3300 Function Generator
8405A Vector Voltmeter
423A Crystal Detector
180A Oscilloscope
0.001 μF Capacitor
10kΩ Resistor
331A Distortion Analyzer
8556A Audio Spectrum Analyzer System

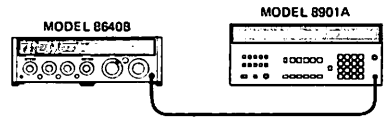
Total Time to Make All Listed Measurements:
5 hours.

Comments

All tests check only a few points, many of which are not in the specified regions.

K. COUNTER ACCURACY

Equipment



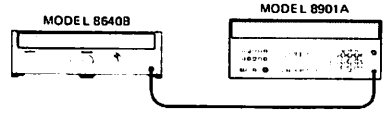
8901A Modulation Analyzer

TIME: 2 minutes.

PROCEDURE: Turn off 8640 modulation. Set 8640 to a convenient RF frequency like 500 MHz and press lock button. Connect 8901A to 8640. Select frequency measurement. Enter 7.1 special to obtain maximum resolution. Enter 8640 displayed frequency on the keyboard of the 8901A and press the "MHz" key. Select frequency error measurement. The 8901A now displays the 8640 frequency error in kHz. If a display of parts-per-million error is desired, enter the 8640 displayed frequency in MHz times 10^{-1} (i.e., for 500 MHz, enter 50), then press % ratio. The 8901A now displays frequency error in parts-per-million.

L. RF LEVEL ACCURACY
(Functional Check Only)

Equipment:



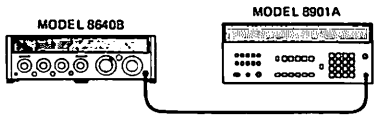
8901A Modulation Analyzer

TIME: 10 minutes.

PROCEDURE: Turn off 8640 modulation. Set 8640 output level to +10 dBm. Connect 8901A to 8640. Select RF level measurement on 8901A. 8901A display now reads in watts. To display output level in dBm, enter 0.001 and dB ratio. The 8640 can now be tuned to any frequency where measurements are desired. In RF level the measurement range is approximately +30 dBm to −30 dBm. To check the output level over a wider dynamic range, select the tuned RF level measurement and re-enter 0.001 dB ratio. The 8640 attenuator can now be checked over a range of +20 dBm to −50 dBm. At the lowest levels, resolution is poor.

M. HARMONIC DISTORTION
(Function Check Only)

Equipment:



8901A Modulation Analyzer

TIME: Depends on the number of frequencies chosen.

PROCEDURE: Turn off 8640 modulation. Set 8640 to the desired level plus frequency. Connect the 8901A to the 8640. Select Tuned RF Level measurement. Enter 3.1 special (above 2 MHz) for narrow IF operation and 8.3 special to eliminate error displays. Enter the 8640 frequency on the 8901A keyboard. Depress dB ratio. Manually tune to the desired harmonic and read its level relative to the carrier. In some cases, dynamic range may be limited by low frequency spurious signals generated inside the 8901A. The effect of these can be eliminated by initiating a 100 kHz step down on the keyboard each time the analyzer is returned to the carrier or harmonics, and before making measurements. Stepping down 100 kHz causes the IF filter to eliminate all low frequency spurious.

8660 less expensive more phase noise

8662 expensive sig Gen. less phase noise

8903 – Audio analyzer – go & return.

8901 – Mod Analyser?